ANL/APS/TB-14

APS Beamline Design and Construction Requirements:
A Reference Manual for Designers and Builders

Version 1.0

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SECTION I. DEFINITIONS, GUIDELINES, AND REVIEW CRITERIA

1 INTRODUCTION (Rev July 21, 1998)

1.1 About the Advanced Photon Source

The Advanced Photon Source (APS) at Argonne National Laboratory is a third-generation synchrotron light source optimized for using insertion devices as high-brilliance sources of hard x-rays.

The forefront capabilities of the APS will be available to qualified users, who may participate at the APS as either members of Collaborative Access Teams (CATs) or Independent Investigators (IIs).

A CAT is an entity organized to develop and operate one or more of the 35 available APS sectors. (Each sector consists of an insertion device beamline and an adjacent bending magnet beamline.) Each CAT will use its own funds to develop its sector(s), that is, to design, construct, and install the beamline components. A CAT must submit a scientific proposal, a conceptual design, a management plan, and construction and operations funding. Once these requirements have been met, the CAT and the APS sign a Memorandum of Understanding (MOU). [The process for the submission and review of proposals to form CATs, requirements for management plans, and requirements for funding letters are outlined in Guidelines and Forms for Proposals to Establish Collaborative Access Teams at the Advanced Photon Source (November 1990) and The Advanced Photon Source User Policies and Procedures (July 1993). These documents are available from the APS User Office.

Independent Investigators do not participate in beamline design and installation; their experiments are conducted on beamlines constructed by CATs. However, they may wish to bring experimental equipment and/or optics of their own to be used on a beamline, as permitted by the host CAT. Equipment brought by the Independent Investigator must conform to all applicable safety regulations of the APS and the CAT and incorporate measures for the protection of the storage-ring vacuum and beamline components.

1.2 About this Manual

This manual is designed to be used as a reference tool for CATs that have received scientific proposal approval. Written as a guide for the design and construction of beamlines and experiment stations at the APS, it contains three major sections. Section I describes the structure of a beamline, defines the responsibilities associated with beamline design and construction, and describes the review process from conceptual design to operational readiness. Section II includes copies of beamline-related policies and design report guidlines, and Section III contains technical updates. As new guidelines, policies, and updates are developed and issued, they can be inserted in the appropriate sections.

2 BEAMLINE DEFINITIONS AND RESPONSIBILITIES (Rev. July 21, 1998)

2.1 Definitions

Beamline: In a general sense, a beamline is the transport through which x-rays are propagated from the source to the experimental station. It includes the enclosure shielding, as well as the optics that define the beam characteristics. At the APS, the user's portion of the beamline starts at a window or differential pump, which isolates the downstream beamline from the front end, the radiation source and the accelerator systems. This pump or window is located in the experiment hall immediately outside the storage-ring shielding.

Beam Transport: The chambers, typically vacuum chambers, through which the x-ray beam is propagated and which provide shielding from scattered radiation, as needed.

Equipment Protection System: The equipment protection system (EPS) consists of the instrumentation, including interlocks, designed to prevent equipment on the beamline from being damaged from thermal loads, radiation, etc.

Experiment Stations: At the APS, experiment stations are shielded enclosures that contain the experimenter's equipment. When beamline shutters have been closed and the personnel safety system (PSS) interlocks have been satisfied, personnel can enter the enclosure. The experiment stations are constructed of panels of lead and steel. Typically, as described above, they can contain the experiment-specific optics, samples stages and environments, analyzing optics, and photon detectors.

First Optics Enclosure: The first optics enclosure (FOE) is a shielded experiment station containing the beamline optics that accept the full spectrum of the x-rays from either an insertion device or bending magnet and the optics that select the portion of the spectrum to be transmitted down the beamline.

Front End: The front end (FE) is an ultrahigh-vacuum transition that provides for the extraction of radiation from the storage ring. The front end contains radiation collimators, masks, shutters, photon beam position monitors, and vacuum isolation valves. (The APS is responsible for the design, construction, and operation and maintenance of all APS front ends.)

Personnel Safety System: The Personnel Safety System (PSS) consists of the instrumentation controls that are configured to provide for the safety of personnel using the radiation beam.

White Beam: The spectrally unmodified radiation beam from the insertion device or bend magnet.

2.2 Responsibilities

The responsibility for the design, construction, installation, operation, and maintenance of the beamline components will be the responsibility of the CAT as described in The Advanced Photon Source User Policies and Procedures. However, the beamline components and any other equipment that is installed at the APS must be designed so that it conforms to all applicable safety regulations and incorporates acceptable measures for the protection of personnel, equipment, and the storage-ring vacuum. In general, responsibility is assigned as follows:

2.2.1 APS Responsibilities

- Design, construction, installation, operation, and maintenance of all bending magnet and insertion device sources.
- Design, construction, installation, operation, and maintenance of all front-end components.
- Design, construction, installation, and maintenance of all beamline personnel safety system interlocks.

2.2.2 CAT Responsibilities

- Design, construction, and installation of all beamline components (including first optics, beam transport, additional optics, and experiment stations and any other equipment at the APS). (Note: As described above, interlocks and controls related to personnel safety will be installed and maintained by the APS.)
- Design, construction, and installation of all the equipment inside the experiment stations, excluding the personnel safety system equipment.

3 REVIEWS: GENERAL INFORMATION (Rev. July 21, 1998)

Every APS beamline is subject to the following reviews: Conceptual Design, Preliminary Design (30% completion), Final Design (90%), Construction Readiness, Commissioning Readiness, and Operational Readiness. For a given beamline, these reviews may be repeated if significant design modifications occur.

Purpose

Beamline reviews are conducted to ensure that the components and equipment are (1) optimized for the proposed scientific program and (2) satisfy all APS, ANL, and DOE requirements for safe operation. (The documentation developed for the reviews and during the review process will be kept on file in the APS User Office, permanently accessible for reference whenever information about the beamline is required.) In addition, at each review, AutoCAD drawings of the beamline and its components will be filed in the APS Design Exchange (DX), which will enable current electronic or paper copies of beamline layout to be accessed as needed.

Participants

Conceptual Design Reviews are conducted by the APS Instrumentation Feasibility Committee who report their findings to the APS. All other beamline reviews are conducted by the APS Beamline Review Committee, which is made up of members of the APS staff who can assess the beamline design, as well as construction, operation, and ES&H requirements. The APS may choose to expand the committee as needed in the review process.

Process

All reviews should be scheduled through the APS User Office.

Conceptual Design Reviews

For these reviews, 10 copies of a Conceptual Design Report (CDR) should be submitted to the APS User Office. Review Committee members will review the CDR and, if necessary, arrange to have the User Office schedule a meeting with the CAT. When the Review Committee has prepared its recommendations, it will transmit them to the APS for approval.

Preliminary and Final Design Reviews

For these reviews, 15 copies of a Preliminary or Final Design Report (PDR or FDR) should be submitted to the APS User Office. Review Committee members will review the design report, evaluating it according to the criteria detailed in the guidelines in Section II. This process may involve several iterations between the Review Committee and the CAT.

4 CONCEPTUAL DESIGN REVIEW (Rev. July 21, 1998)

A conceptual design defines the functional requirements of the beamlines in a sector. All members of a Collaborative Access Team (CAT) should be involved in the development of the conceptual design because the primary scientific objectives and programs are defined during this process. In addition, all CAT members should be in concurrence about the functional requirements of the beamlines. The conceptual design report (about 10-20 pages of text) should include the following:

• A Brief Statement of the Scientific Objective of the CAT (1 page)

• Rationale for the Choice of Insertion Device

State the short- and long-term goals for the device.

• Spectral Requirements

State the spectral requirements of the beamline and describe how these requirements will be met. Examples of spectral requirements are monochromaticity, tunability, polarization, etc.

• Optical Design

State the optical objectives of the beamline, and describe how these requirements will be realized. Examples of optical requirements are

- horizontal and vertical size and divergence of the beam at the experiment
- adjustability of optical parameters to meet various requirements
- range of variability of optical parameters

State the rationale for the chosen optical design. Include alternative designs considered, if any, and the reasons for choosing the current design.

Define the optical elements and their performance requirements. Examples of optical element design are

- surface finish and surface figure
- positional and angular stability and reproducibility
- thermal stability

Include any known information indicating that such performance criteria have been met.

• Success of Overall Beamline Design

Discuss the elements essential for the success of the beamline design, and describe the impact of any marginal failure in the design performance on the scientific objectives of the proposed program.

• R&D Requirements

Describe any R&D needed to meet the specifications of the design, and explain how this R&D will be conducted. If R&D is required to complete the final design, outline the schedule of R&D activities. State the backup plan to be followed if R&D does not produce the anticipated results. Is it expected that any portion of the R&D be carried out by the APS staff?

• Drawings and Ray Diagrams

Provide a plan view and elevation view of the beamlines with sketches of supports, experiment station, optics enclosure, location of instruments and electronics, etc.

A ray diagram with extremal rays should be shown on a separate drawing (using a 10-fold compressed scale along the beamline length) to assure that the apertures, slits, masks, optics, etc. have been adequately considered.

The purpose of these drawings is to test the proof-of-principle and the feasibility of the optical designs. It should be understood that these designs will change with a better definition of parameters.

5 PRELIMINARY BEAMLINE DESIGN REPORT -- December 5, 1994

5.1 Preliminary Beamline Design: General Guidelines

The Preliminary Design of the beamline represents an approximately 30% design level of each of the beamline components. This level of design permits the CAT to develop cost estimates for the construction of the beamline, as well as a realistic timeline for completion of the construction tasks. A committee from the APS has been charged with reviewing the Preliminary Design Reports and has established the evaluation criteria described below.

The Preliminary Beamline Report is expected to expand upon the Conceptual Design Report in the following areas:

- Beamline Layout
- Component Design
- Work Breakdown Structure
- Cost and Schedule
- Additional Operational Requirements
- Safety Analysis
- R&D Plans

We suggest that the CATs ensure that each vendor has a valid QA and QC capability before a contract is signed.

If an advanced plan for procurement is to be developed, the procurement department should be involved in this activity to ensure that the schedules are realistic. This also permits the CAT to discuss issues related to vendor contracts, such as the use of sole-source or fixed-price contracts, with its procurement personnel.

5.2 Preliminary Beamline Design: Specific Guidance and Review Criteria

5.2.1 Beamline Layout

Show the layout of the beamline on the APS defined sector and include all its components. AutoCAD drawings of the sectors have been previously provided to the CATs. Include the assignment of space for electronics racks, working tables, etc. Indicate the overall plan for beamline vacuum; e.g., identify high vacuum and UHV segments. Demonstrate how this plan complies with the APS vacuum policy. Refer to APS Technical Bulletin ANL/APS/TB-9 (February 1993) for information on sector layout, utility specifications, and egress considerations. Indicate your overall plan for survey and alignment. Give a brief overview (in a few paragraphs) of the scientific program to be carried out on this beamline.

Criterion 5.2.1.1
An overall beamline/sector layout has been provided showing beamline components, personnel safety system components, support equipment (racks, etc.), and furniture.

Criterion 5.2.1.2
The overall beamline layout and components are compatible with the intended science. The following will be considered in the evaluation:

- The compatibility of the selected insertion device(s) with the scientific program.
- Choice of monochromator and mirrors and their placement.
- Clear identification of where white beams and monochromatic beams will be propagated.

- CAT-specific science issues.

Criterion 5.2.1.3

Life Safety Code compliant egress aisles are indicated on the sector layout. Designs shall provide for aisles free of obstructions with 400' maximum distance to an exit and 50' maximum dead-end pockets. The location of beamline duck-unders shall be identified.

Criterion 5.2.1.4

Some indication of the survey and alignment plan is provided. If such a plan is included in the Preliminary Design Report, then it will be reviewed. If one is not included, then the report should include reference to the APS beamline survey plans. The following items will be considered for comment:

- Installation and alignment procedures and tolerances.
- Support system stability.

5.2.2 Component Designs

We encourage the designers to use any of the applicable Standard Component drawings currently available from the APS Design Exchange. Both standard and non-standard beamline components will also be reviewed. Safety is of primary concern; however, advice and guidance will be given to the user with respect to functionality and quality assurance. Present drawings of non-standard components in sufficient detail to allow the reviewer to evaluate the functionality of the design and the adequacy of the space allocated for the components.

Criterion 5.2.2.1

Each component is identified as being in one of the following categories:

- APS standard components that have been adopted without modification.
- APS standard components that have been modified (explain modifications).
- Non-standard components.

Criterion 5.2.2.2

Adequately detailed drawings are provided for all non-standard components.

Criterion 5.2.2.3

Appropriate specifications are provided for non-standard components. Consider design aspects such as:

Thermal engineering:

- Thermal load on the component (identify tools used in the analysis).
- Cooling system design and analysis (identify tools used in the analysis).
- Material properties assumed and safety margins allowed.

Mechanical design:

- Motion structure design and reliability.
- Motion/vacuum joints identified clearly.
- Fail-safe design.
- Motion control and interlock interface.

Radiation compatibility of materials.

Criterion 5.2.2.4

The Preliminary Design is in compliance with the APS vacuum policy at the component level. Non-compliance with APS vacuum policy recommendations requires justification. The following items will be considered in the evaluation:

- Vacuum requirement for the component.
- Vacuum structure design.
- Material/vacuum compatibility.
- Coolant/vacuum joints identified clearly.
- Vacuum materials identified.

Criterion 5.2.2.5

Optical apertures and shielding apertures are shown to be adequate. The following items will be considered in the evaluation:

- Apertures are consistent with the beamline optical design, ray-tracing, and general layout.
- A reasonable safety margin exists (especially for white beam).

5.2.3 Work Breakdown Structure

A detailed Work Breakdown Structure (WBS) should be developed to account for each of the components that make up the beamline. For the purposes of this review, beamline components are instruments such as filters, slits, masks, mirrors, monochromators, windows, beam position monitors, etc. Attachment 1 presents a typical WBS for a generic insertion device beamline.

Criterion 5.2.3.1

A work breakdown structure, consistent with the design and broken down to the component level, is provided.

5.2.4 Preliminary Cost Estimates and Schedules

This portion of the Preliminary Design Review is intended to ensure that costs are reasonably estimated and that the completion schedule is realistic. Indicate your plan for including a contingency allowance in your cost estimates (for example, adding contingency as a line item or building it into individual component costs).

A cost estimate for the construction of each WBS item should be developed. Also, detailed schedules for each of the construction activities should be prepared for every WBS item, based on the information at hand. The total construction cost will be the sum of the following:

1. Effort costs for engineering design. These activities are usually done by the scientific and engineering staff, design staff, and drafting staff.
2. Cost of procurement and/or fabrication of components. In developing schedules for procurement of components requiring a long lead time, an advanced plan for procurement should be developed.
3. Effort costs for assembly, inspection, testing, and installation (integration) of the entire beamline on the APS Experiment Hall floor, and for the checkout of the beamline. The work on inspection, testing, and checkout is typically done by scientists and/or engineers, while the assembly and installation work is usually done by support staff, technicians, etc.
4. Cost of utilities (power cables, water pipes, valves, gas manifolds, communication cables, connectors, utility and cable trays, tray supports, etc.), including the costs of installation.

The schedule of work should include, for each relevant element of the WBS, the proposed or actual starting date and a completion date for each of the following activities: final engineering design, procurements, fabrication tasks, assembly of components and their testing, installation (or integration) of the beamline, and checkout of the beamline. The last two activities are carried out in the APS Experiment Hall. We

strongly recommend the use of project management software, which facilitates establishment of milestones for the activities and measurement of their progress. Users can also use such software for resource management and leveling.

Criterion 5.2.4.1
Cost estimates and schedules are provided and are consistent with the WBS.

Criterion 5.2.4.2
The engineering design effort costs have been included.

Criterion 5.2.4.3
The cost estimates for procurements and fabrications are reasonable. Include the costs for:

- Mechanical Components
- Experimental Stations
- Transports and Supports
- Personnel Safety System and Equipment Protection System
- Utilities
- Survey and Alignment
- Sum of above for each beamline

Criterion 5.2.4.4
The schedule is reasonable. In addition to giving starting and completion dates for the above-mentioned activities associated with each WBS element, the beamline designer should also consider developing schedules for the following activities:

- Survey and alignment (at the site).
- Final beamline design and safety documentation and review.
- Safety/Interlocks documentation and installation.
- Construction readiness documentation and review.
- Commissioning readiness documentation and review.
- Operational readiness documentation and review.

5.2.5 Additional Operational Requirements

It is important to plan the cost and schedule for finishing out the space assigned to the CAT in the Laboratory/Office Modules (LOMs). This includes office furniture, office partitions, and special equipment in the CAT laboratories. A separate document, entitled A Guide to the APS Lab/Office Modules, was sent to all CAT Directors in December 1993. Copies of this document are available upon request from the APS User Office.

In addition, any special requirements for the operation of the beamline equipment should be indicated. APS Technical Bulletin ANL/APS/TB-9 (February 1993) describes the standard utilities provided by the APS in each of the sectors. Examples of special needs in the sector and in the LOM include local air-conditioning capability, local ventilation, exhaust for specialty or toxic gases, radioactive sample or chemical handling capability, electrical loads greater than the APS standard supplies, special telecommunication requirements, etc.

Criterion 5.2.5.1
Any special requirements for the operation of the beamline equipment are indicated. The special requirements will be reviewed for consistency with beamline needs and compatibility with the installed conventional facilities. Guidance will be sought from APS Conventional Facilities personnel as appropriate.

Criterion 5.2.5.2

If white beam is to be propagated in an experimental station, a preliminary analysis of ozone production and the general plan for mitigation is provided.

Criterion 5.2.5.3

Cost and schedule information is provided for LOM build-out. The beamline preliminary design can be approved prior to the submission of this material. If provided, this information will be transmitted to the LOM review committee. The User Technical Interface is the users' point of contact for arranging for LOM reviews and construction.

5.2.6 Preliminary Safety Analysis

A preliminary safety analysis for the operation of the beamline should be provided. This analysis should address shielding requirements, safety interlock logic for the Personnel Safety System and Equipment Protection System, and all special needs related to beamline operations, such as the capabilities to handle hazardous gases, radioactivity, bio-hazards, etc. The shielding requirements applicable to most beamline configurations are discussed in detail in Guide to Beamline Radiation Shielding Design at the Advanced Photon Source, ANL/APS/TB-7.

Criterion 5.2.6.1

The shielding design is in compliance with APS shielding standards. Items to be reviewed include the following:

- Experimental stations and beam transports meet APS shielding specifications.
- Shielding designs that are not APS standard shielding designs are identified and an analysis of the shielding is provided.
- Complete anamorphic ray tracing analysis for bremsstrahlung is provided.
- Analysis of shielding designs is provided for special insertion devices, if any.
- Analysis of shielding designs is provided for white-beam transports, if applicable.
- Radiation analysis is provided for non-high-vacuum beamline components, if any.

Criterion 5.2.6.2

A preliminary safety analysis is provided for the beamline Personnel Safety System. The APS will install and maintain the beamline Personnel Safety System. The analysis is intended to provide feedback, early in the design process, on the design of the system and its ability to meet the user's needs and APS requirements. The Preliminary Design Report shall include the following:

- For each mode of operation (e.g., personnel have access to the FOE, monochromatic beam in station B, etc.), the necessary configuration of beamline safety components (e.g., which shutters are closed, have the experimental station interlocks been satisfied, etc.) are defined.
- The beamline layout clearly identifies the location of beamline Personnel Safety System components (e.g., interlocks).
- User equipment that has the potential to interfere with or block access to Personnel Safety System components (e.g., audio alarms, visual alarms, station search buttons, interlock switches, etc.) is identified.
- Specific problems and concerns are identified.

Criterion 5.2.6.3

A preliminary safety analysis is provided for the beamline Equipment Protection System. The safety analysis should demonstrate that the EPS design is compatible with the APS Equipment Protection System logic, and in compliance with the APS policy on white-beam beamline components.

The Preliminary Design Report shall include the following:

- Identification of the components to be interlocked.
- A preliminary block diagram of the Equipment Protection System.
- A preliminary description of the computer/controller configuration and interface to APS system plans.
- Identification of any special problems or concerns.

Criterion 5.2.6.4

A preliminary safety analysis is provided for program-specific hazards. Program-specific hazards such as the need to handle hazardous gases, radioactive materials, and biohazards should be identified and preliminary plans for mitigating the hazards should be addressed. Guidance will be sought from outside the committee as needed.

5.2.7 R&D plans

Many CATs are planning to carry out instrumentation R&D in preparation for the design and construction of certain beamline components. The Preliminary Design Report should therefore include an R&D plan and a list of R&D milestones and schedules. CATs should ensure consistency between R&D schedules and construction schedules; that is, the R&D milestones for a component should be met well before the activities related to its construction begin.

Criterion 5.2.7.1

R&D schedules are consistent with construction schedules.

Attachment 1

5.0 Generic CAT Work Breakdown Structure

5.1 Generic ID Beamline

5.1.1 First Optics Enclosure
- 5.1.1.1 User Filters
- 5.1.1.2 Collimator
- 5.1.1.3 Support Structure
- 5.1.1.4 ID White Beam H & V Slits
- 5.1.1.5 Support Structure
- 5.1.1.6 ID Double Crystal Monochromator
- 5.1.1.7 Integral Shutter and Stops
- 5.1.1.8 Support Structure
- 5.1.1.9 Dual W/M Window
- 5.1.1.10 Vacuum Components (Bellows, Valves, Pumps, Gauges, etc.)
- 5.1.1.11 Penetration Tube (Bremsstrahlung Shielded)
- 5.1.1.12 First Optics Enclosure Hutch

5.1.2 X-Ray Scattering Station
- 5.1.2.1 6" I.D. Pipe & Stand
- 5.1.2.2 Dual W/M Window
- 5.1.2.3 Integral Shutter & Stops
- 5.1.2.4 Support Structure
- 5.1.2.5 Vacuum Components (Bellows, Valves, Pumps, Gauges, etc.)
- 5.1.2.6 Penetration Tube (Bremsstrahlung Shielded)
- 5.1.2.7 X-Ray Scattering Hutch
- 5.1.2.8 Shielded Cabinet (2)
- 5.1.2.9 Support Structure
- 5.1.2.10 Spectrometer
- 5.1.2.11 Slits
- 5.1.2.12 Detectors
- 5.1.2.13 NIM Electronics
- 5.1.2.14 Additional Equipment
- 5.1.2.15 Data Acquisition/Motion Controls

5.1.3 End Station
- 5.1.3.1 Mono Beam H & V Slits
- 5.1.3.2 Support Structure
- 5.1.3.3 Shielded Cabinet
- 5.1.3.4 4" Shielded Transport (2)
- 5.1.3.5 4" I.D. Shielded Bellows (1)
- 5.1.3.6 Mono PBPM
- 5.1.3.7 Support Structures
- 5.1.3.8 Window 4" I.D.
- 5.1.3.9 Shielded Cabinet
- 5.1.3.10 Penetration Tube (Bremsstrahlung Shielded)
- 5.1.3.11 ID Diagnostic Station Hutch
- 5.1.3.12 Data Acquisition/Motion Controls
- 5.1.3.13 Support Structure
- 5.1.3.14 Diffractometer
- 5.1.3.15 Detectors and NIM electronics

5.1.4 Personnel Safety Interface

5.1.5 Equipment Protection Interface

5.1.6 Beamline Controls

5.1.7 Survey and Alignment

5.1.8 Power and Utilities

Final Beamline Design Report

Guidelines and Review Criteria (SCD 1.20.95)

6 Final Beamline Design Report (FDR) Overview

The Final Beamline Design Report is part of the Advanced Photon Source (APS) beamline review process and should be planned for when approximately 90% of the total beamline design has been completed. Fifteen copies of the FDR are to be submitted to the APS Users Office. Approval of the Collaborative Access Team's (CAT) designs described in the report is required prior to installation of beamline components in the APS Experiment Hall. Components that have a long lead time for design or procurement can be reviewed separately from the remainder of the beamline, but enough information must be provided so that the reviewer can understand the context in which the component is to be used. Those components which are part of the APS standard component list need not be reviewed for their individual performance; however they should fit into the general scheme of the total beamline performance.

The review of the Preliminary Beamline Design Report (PDR) focused on the layout of the beamline as a whole and at a level that would permit the beamline components to be designed independently of each other. The final design report will focus on aspects of safety, scheduling, required APS support, and updating the information provided in the PDR. The topics to be covered in the FDR are:

- Layout Update
  - ❖ Identify changes from PDR layout
  - ❖ Provide survey plan and include expected APS support
  - ❖ Update the ray traces provided in the PDR
- Component Design Update
  - ❖ Provide component final design (reference if APS standard components are used)
  - ❖ Assure compliance with the APS beamline vacuum policy
- Schedule
  - ❖ Update PDR Work Breakdown Structure (WBS) based schedule
  - ❖ Provide installation schedule
  - ❖ Identify expected APS craft support and provide schedule
  - ❖ Provide survey schedule
- Safety
  - ❖ Provide final Personal Safety Systems (PSS) requirements
  - ❖ Provide Equipment Protection Systems (EPS) logic and interface requirements
  - ❖ Describe final shielding design
  - ❖ Identify chemical, electrical, fire, and other hazards that impact beamline design, and describe means to mitigate the identified hazards
  - ❖ Identify program-specific hazards (e.g., high powered lasers, biohazards, chemical, etc.)
- Special Operating Requirements Update
  - ❖ Identify special conventional facilities requirement

All significant changes from the information provided in Preliminary Design Report (PDR) should be clearly noted. (Significant in the sense that the changes will affect the scope of the beamline capabilities, functionality, constructability, or safety.)

Beamline designers should keep in mind in the design process that, as part of the Installation Readiness Review, the beamline components will be reviewed for compliance with standards such as NEC and those specified in the ANL ESH manual.

In reviewing design reports, the APS will note concerns that have been identified, but, ultimately, it is the CAT's responsibility to build and operate a productive facility that meets applicable safety standards.

Final Beamline Design Report Review Criteria

6.1 Layout Update

Criterion 1.1
A plan and elevation of the beamline layout has been provided with clearly identified beamline components (e.g., slits, shutters, mirrors, monochromators, shutters, stops, etc.), beamline support facilities (e.g., beamline controls and data acquisition electronics, compressed gas storage areas, etc.), and aisle ways. CAD files of the layout have been provided to the Design Exchange.

Criterion 1.2
Changes from the PDR layout have been clearly identified, and the impact on the beamline functionality is described.

Criterion 1.3
A survey and alignment plan has been provided including the general scheme and the required survey fiducials.

Criterion 1.4
Utility distribution is specified. This may be done with a layout drawing that clearly shows, as appropriate, information such as: tap, outlet, and breaker locations, pipe sizes, identification of electrical circuits, design of utility support structures, locations of heat exchangers, etc.

Criterion 1.5
Changes from the PDR ray traces for optical apertures and bremsstrahlung shielding have been provided with the changes from the PDR ray traces clearly identified.

6.2 Component Design Update

Criterion 2.1
Updated drawings, typically assembly drawings, and/or performance specifications have been provided for each beamline component at a level so that the reviewer can understand how the device is to function.

Criterion 2.2
Documentation that the beamline is in compliance with the Vacuum Policy for APS Beamlines (refer to ANL/APS/TB-14) has been provided. The vacuum levels in each beamline segment and the location of in-vacuum, liquid-coolant joints should be indicated.

Criterion 2.3
Beamline components were identified in the PDR as being either standard components, modified standard components, or user designed devices. State what changes, if any, there have been in any components.

6.3 Schedule

WBS-based schedule information has been provided with the FDR and will provide the basis for proceeding with the beamline construction. Much of the schedule information required in the FDR is the useful to both the APS as well as the CAT to ensure that the required resources can be provided.

Criterion 3.1
An installation schedule has been provided. The schedule should identify design, fabrication/procurement, installation, hook-up, and commissioning activities at a beamline-component level.

Criterion 3.2
Components that will be procured through the APS are identified, and the required delivery date provided.

Criterion 3.3
A schedule for APS support is included for:

- skilled trade support (e.g., electricians, plumbers, etc.)
- survey and alignment
- Personnel Safety System installation and check-out

6.4 Safety

Criterion 4.1
The PSS requirements of the beamline have been provided, including:

- Identify components that need to be interlocked
- Identify components that need administrative control, and describe the nature of the administrative control (who needs to do what)
- Indicate the location of PSS hardware (e.g., control panels, search buttons, routing of PSS wire-ways, etc.)
- Provide a logic table to describe the configuration of the beamline components for the different modes of a beamline (e.g., monochromatic, white beam, station pass through, off-line, etc.)
- Provide a logic table to describe the required status of the beamline components to define the access to each experimental station (i.e., station secured no personnel access, personnel access permitted to station, or station administratively off-line).

If this information was provided with the PDR, any changes should be noted.

Criterion 4.2
An updated EPS description has been provided. An identification of monitored components, the design logic, and interface requirements should be included. If this information was provided with the PDR, any changes should be noted.

Criterion 4.3
The specification of beamline shielding is provided.

- Describe the type of radiation to be propagated (white, monochromatic, or "pink") in each portion of the beamline
- Identify where non-APS designs were used for shielding
- If shielding other than the APS standard design is used, an analysis must be provided assuring the shielding meets the same design criteria as described in ANL/APS/TB-7 and ANL/APS/TB-20

If this information was provided with the PDR, any changes should be noted.

Criterion 4.4

The ozone hazard created by the beamline is described, as is the plan to mitigate the hazard. (Refer to Guidelines for Ozone Mitigation at the APS, within ANL/APS/TB-14.)

Criterion 4.5

Identify chemical, electrical, high power lasers, biohazards, and any other hazards that will impact beamline design, and describe the plans to mitigate these hazards. When the hazards are beyond the expertise of the Beamline Design Review Committee, then advice and review will be sought from outside the committee.

- For beamline electrical/electronic instrumentation, identify potential electrical hazards and mitigation plans (e.g., grounding plans for ion pumps and vacuum chamber with ion gauges)
- Beamline designs may need to incorporate the means to mitigate hazards associated various chemicals. Identify hazardous materials storage areas, exhaust systems, gas handling systems, etc., and describe the plans for mitigating the hazards

Criterion 4.6

Identify potential fire hazards including quantities of flammable liquids and gases in experimental stations and along the beamline. Identify enclosed areas that will be occupied during normal operations (e.g., a sample preparation clean area with roof). Of course, experimental stations are not occupied during normal station operations.

6.5 Special Operating Requirements Update

Criterion 5.1

Identify special, (i.e., those beyond the capacities described in ANL/APS/TB-9) conventional facilities requirements.

7 Beamline Construction (Rev. July 21, 1998)

After the beamline Final Design Report has been reviewed and approved, the CAT can begin the installation of the beamline components on the experiment hall floor. The typical sequence of beamline installation is:

1. experiment stations constructed,
2. PSS and utilities installed,
3. PSS and shielding validated, and
4. beamline components installed.

Because access to the stations is needed to verify the integrity of the station shielding, in general, beamline components should be installed after the shielding has been verified or arrangements have been made with the beamline commissioning team.

Prior APS approval is required for all installations and modifications of permanent structures in the APS experiment hall and LOMs. If the facility design has not been explicitly approved via the beamline design review process described above in parts 3 and 4 and in the beamline design report guidelines in Section II, then the CAT shall submit its designs, including a written programmatic justification to the User Technical Interface Group Leader, who will coordinate the design review and approval.

For the installation of beamline and LOM facilities, the APS will make licensed and qualified electricians, pipe fitters, carpenters, and other "skilled trade" workers available to APS users for those beamline construction and installation tasks (hutch installation, electrical distribution, pipe fitting, etc.) that require these types of workers, and for any other tasks that users wish to have done by such workers. User institutions may not contract directly with contractors for any construction work on the APS site. (Refer to the User Policies and Procedures for Use of Third-Party Contractors at the APS for details.) Examples of construction work include:

- Changes to the physical plant, including any drilling into floors, walls or ceilings, or altering of any permanent structure.
- Use of industrial lifts, scaffolds or cranes.
- "Hard-wire" installation or tie-in to facility utilities, including electrical, plumbing, ventilation, or water systems.

Contact an APS Floor Coordinator to arrange for on-site time and materials construction support.

It is recommended that, early in the utility design process, the CAT designers contact an APS Floor Coordinator to arrange for a review of the conceptual layouts and installation plans. The APS engineering support will work with the CATs to address facility tie-ins, available utility options, and contractor services.

The CAT is responsible for keeping current beamline and facility drawings on file with the APS. Drawings should be kept updated to reflect as-built conditions and, as facilities change, should be submitted as design report updates.

8 Beamline Commissioning (Rev. July 21, 1998)

A beamline commissioning process has been instituted to ensure that all systems are in place so that a beamline can perform in a safe and efficient manner. The APS will:

- verify that CAT safety management plans are in place,
- ensure the radiation source safeguards are operational,
- ensure the front end is operational and its safeguards, the equipment protection system and the personnel safety system, are operational,
- install, maintain, and validate the beamline the personnel safety system (PSS), and
- validate the integrity of the beamline shielding.

The beamline commissioning is coordinated by the XFD Associate Division Director for Operations (ADD-Ops). A Beamline Commissioning Readiness Review Team (BCRRT), composed of APS and CAT representatives is formed to develop the specific plans for the beamline commissioning. For more information about the commissioning process contact the ADD-Ops.

SECTION II. BEAMLINE-RELATED POLICIES

1 Service-Corridor, Exit Aisles and Duck-Unders on the APS Experiment Hall Floor (May 1994)

2 Guidelines for Ozone Mitigation at the APS (May 1994)

ACGIH Threshold Limit Values (1993-194)

Reviewed and updated January 11, 2011

Guidelines for Ozone Mitigation at the APS

May, 1994
Advanced Photon Source

Guidelines for Ozone Mitigation at the APS

Introduction

The Advanced Photon Source (APS) will produce x-ray beams of sufficient power to generate considerable amounts of ozone. Appropriate measures must be taken to ensure that personnel are not exposed to ozone concentrations that exceed the maximum permissible limits of applicable regulations. The purpose of this document is to give APS users the necessary information to formulate plans to deal with the ozone production on their beamlines.

In the following, the pertinent regulations will be discussed, ozone production calculations will be described and the results given, and examples for mitigating problem levels of ozone will be given.

Ozone Exposure Guidelines

The U. S. Department of Energy requires that its facilities use the requirements of ACGIH (American Conference of Governmental Industrial Hygienists) in matters of industrial hygiene.[1] The relevant passages of the ACGIH guidelines[2] are reproduced as Appendix A. Care should be exercised in the reading of the ACGIH document; current values are given, along with a notice for intended changes. Ozone is one of the substances for which ACGIH proposes changing the recommended exposure levels. The proposed changes will probably be adopted at the annual ACGIH meeting to be held on May 24, 1994. The following assumes that the proposed guidelines (with respect to ozone) were adopted and that the APS will be obligated to follow the new guidelines.

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[1] DOE Order 5480.4, attachment 2, page 2.

[2] 1993-1994 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, ACGIH, Cincinnati, Ohio (1993).

Definitions

In this section, working definitions are given for the various guideline terms. The exact definitions are given in Appendix A.

Exposure limits are of the following types:

TLV-TWA	Threshold Limit Values–Time-Weighted Average
TLV-STEL	Threshold Limit Values–Short-Term Exposure Limit
TLV-C	Threshold Limit Values–Ceiling

The TLV-TWA is the maximum time-average concentration for a normal 8-hour workday and a 40-hour workweek to which workers may routinely be exposed. It is not clear from the guidelines over what period the time averaging should be done for ozone. Because synchrotron workers are well known for not having a normal 40-hour workweek, this value must be adjusted to reflect anticipated shift durations.

The TLV-STEL is the maximum TWA concentration to which a worker may be exposed. Exposures above the TLV-TWA, but below the TLV-STEL should not exceed 15 minutes. There should be at least 60 minutes between such exposures with a maximum of four occurrences per day. The maximum exposure level during a TLV-STEL period is not explicitly given in the ACGIH guidelines. The APS intends to set this maximum at the TLV-STEL limit; i.e., no worker may be exposed to a concentration of ozone above the TLV-STEL at any time.

A TLV-C is a limit above which workers cannot be exposed to for any length of time. This is not a time-weighted average.

Threshold Value Limits for Ozone

The current ACGIH TLV for ozone is a TLV-C of 0.1 ppm (0.2 mg/m^3). The proposed change is for a TLV-TWA of 0.05 ppm (0.1 mg/m^3) and a TLV-STEL of 0.2 ppm (0.4 mg/m^3). As stated above, the APS will follow the proposed TLVs.

The new guidelines are actually less restrictive, because they provide flexibility for dealing with short-term exposures. An example of this at the APS

would be a user entering an experimental station in which a concentration exists that is over the TLV-TWA but below the TLV-STEL. With adequate ventilation, the concentration will drop quickly to levels below the TLV-TWA while the user is working in the station. Under a TLV-C guideline, the user would have to wait for the ozone concentration to drop to below the TLV-C level before entering the station.

Ozone Production

There are two typical situations in which ozone may be produced by a beam-line. The obvious case is an experiment in which the white beam travels through an air path. In this situation, the ozone concentration can quickly exceed the TLV-STEL if appropriate steps are not taken. A second case occurs when a white beam inside a vacuum chamber strikes a component and the consequential scatter ionizes some of the oxygen in the air surrounding the vacuum chamber. Although the rate of production for ozone from scattered radiation is much lower than that for the open white beam, the levels can exceed the TLV-STEL if the ozone concentration is allowed to reach saturation with no ventilation.

Monochromatic beams (defined as below 0.1% bandpass) do not present an ozone problem. Beams that have been reflected from mirrors ("pink beams") will usually produce ozone in a similar way as white beams from the same source. Unless explicit calculations are done to prove otherwise, a white beam that is reflected from a mirror and travels through an air path should be treated as a white beam.

White Beam Directly into Air

The ozone production rate was calculated for three APS sources: Undulator A, Wiggler A, and a bending magnet. Two sets of independent calculations were made; one using the PHOTON program[3] and a second using spectrum generation and absorption routines developed for Mathematica.[4] The results obtained from both methods essentially agreed in all cases. Unless noted

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[3]D. Chapman, N. Gmür, N. Lazarz, and W. Tomlinson, NIM A266, 191 (1988).
[4]These routines are availiable upon request from D. R. Haeffner.

otherwise, for the results that follow the values are from the Mathematica routines because fewer assumptions were needed.

All calculations were done for a storage ring energy of 7.0 GeV and a storage ring current of 100 mA. Also, for all cases it was assumed that the beam passed through a 250-μm Be window. For the Mathematica routines, values from McMaster, et al.[5] were used to calculate the coherent and incoherent cross sections, while the photoelectric absorption coefficients where calculated using the FPRIME[6] program.

The ozone production rate is the energy absorbed by the oxygen (in the air) multiplied by the "G" value. Reported values for G range from 2.69 to 13.8 O_3 molecules per 100 eV.[7] For the current study, a somewhat conservative value of G = 10 O_3 molecules per 100 eV was used. This value is consistent the G value used in preliminary calculations of ozone at the APS.[8]

An Undulator A spectrum was produced by the program US.[9] The undulator parameters were for the maximum power situation (K=2.78) given in a recent APS report describing the enhanced capabilities of Undulator A.[10] This spectrum was fed into Mathematica, and the oxygen absorption and ozone production were calculated. (The comparison calculation using PHOTON approximated the undulator as a bending-magnet.)

The Wiggler A photon spectrum was calculated (in Mathematica) following Dejus, et al.[11] using the wiggler parameters given in an APS Technical Bulletin.[12] The method accounts for the horizontal-angular dependence of the radiated power of the wiggler (i.e., it is not a bending-magnet approxima-

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[5]W. H. McMaster, N. K. Del Grande, J. H. Mallet, and J. H. Hubbell, "Compilation of X-Ray Cross Sections," UCRL-50174 Sec. II Rev. 1, Lawrence Livermore Laboratory (1969).
[6]D. T. Cromer, J. Appl. Cryst. 16, 437 (1983).
[7]C. Weilandics, N. Rohrig, and N. F. Gmür, NIM A266, 691 (1988).
[8]H. J. Moe, "Advanced Photon Source: Radiological Design Considerations," APS/LS/141 Revised (1991).
[9]R. J. Dejus, unpublished.
[10]R. J. Dejus, B. Lai, E. R. Moog, and E. Gluskin, "Undulator A Characteristics and Specifications: Enhanced Capabilities," ANL/APS/TB-17 (1994).
[11]R. J. Dejus, A. M. Khounsary, D. A. Brown, and P. J. Viccaro, NIM A319, 207 (1992).
[12]B. Lai, A. Khounsary, and E. Gluskin, "Wiggler A Characteristics and Specifications," ANL/APS/TB-11 (1993).

tion). The input parameters for the calculation where for a 2.1-cm gap: peak magnetic field–1.0 Tesla, number of periods–28, undulator period–8.5 cm.

The APS bending magnet was calculated for a field of 0.599 Tesla. A horizontal-angular width of 4 milliradians was used.

The ozone production for the three sources as a function of air-path length is shown in Table 1 and Figure 1.

Table 1 Ozone Production by APS Sources

Air path (cm)	Undulator A (g/min)	Wiggler A (g/min)	Bending Magnet (g/min)
0.1	0.00322	0.00413	0.000261
0.5	0.0157	0.0201	0.00127
1	0.0304	0.039	0.00246
2	0.0576	0.074	0.00466
5	0.126	0.162	0.0102
10	0.215	0.276	0.0172
20	0.347	0.442	0.0274
50	0.607	0.760	0.0465
100	0.880	1.09	0.0658

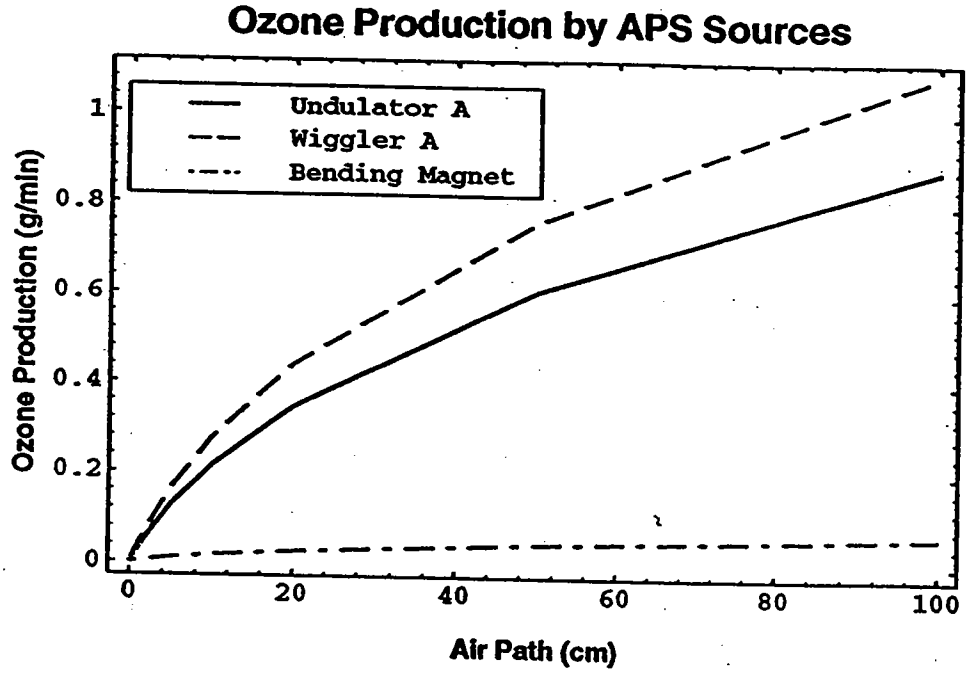

Figure 1 The production of ozone from APS sources as a function of air-path length.

Ozone Production by Scattered Radiation

The ozone production by scattered radiation was calculated for the following situation: a white beam strikes a 50-mm thick piece of copper inside a vacuum chamber made of iron; the thickness of the chamber walls is 2 mm. PHOTON was used to estimate the amount of energy absorbed by a volume of air around the vacuum chamber. The results are given in Table 2. (Please note the change in units for production.)

Table 2 Ozone Production by Scattered Radiation

Source	Production μg/min
Undulator A	190
Wiggler A	410
Bending Magnet	2

Ozone Concentrations in Experimental Stations

The concentration of ozone can be written as

$$C(t) = \frac{P}{V(\alpha+\beta+kP)}\left[1-e^{-(\alpha+\beta+kP)t}\right],$$

where $C(t)$ is the ozone concentration as a function of time, t is time, P is the ozone production rate, V is the station volume, α is the chemical decay constant for ozone, β is the ventilation rate divided by the effective volume, and k is a constant related to the destruction of O_3 by the synchrotron beam. The value for k is not well established[7] and was taken to be 0 for the current study. For α, a measured value of 3.1×10^{-4} s^{-1} was used.[7]

As defined above, the TLV-TWA level of 0.05 ppm of ozone is for an 8-hour day, 40-hour workweek. It is common for workers at synchrotron facilities to work much longer hours. However, it is unlikely that a worker will spend more than eight hours in a day inside a station with ozone levels much above

those of the Experiment Hall. Therefore, the 0.05 ppm ozone concentration will be considered to be appropriate for the TLV-TWA in an experimental station.

In a station, the ozone concentration level has a strong dependence on β. To illustrate this, results from several examples will be given.

Ozone Concentrations with No Ventilation

White Beam Directly into Air

For calculations of ozone concentration, a station volume of 50 m^3 (1765 ft^3) will be assumed. Once a white beam is let into a station, the ozone concentration will gradually build up to a saturation level. The ozone build up for a 10-cm air path of Undulator A with no ventilation ($\beta = 0$) is shown in Figure 2. Saturation occurs after approximately three hours at a level of 118 ppm of ozone. Once this level has been reached, it would take nearly seven hours after the beam has been turned off for the level to drop to 0.05 ppm. This is obviously an unacceptable situation.

With the assumption of $k = 0$, all values of $C(t)$ will simply scale with the production rate. For the same situation described above, the Wiggler A saturation level will be 152 ppm and that of the bending magnet will be 9.4 ppm. Even for the bending magnet, it will take over 4.5 hours for the ozone concentration to drop to an acceptable level.

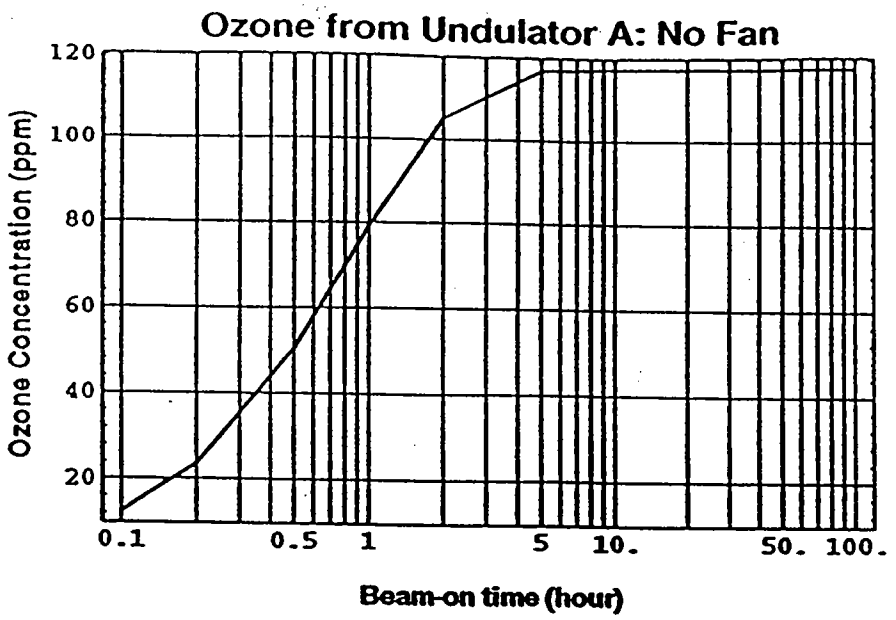

Figure 2 The concentration of ozone inside a 50 m^3 station with no ventilation. The photon source is Undulator A.

Scattered Radiation

The situation for the scattered radiation in the FOEs is considerably less drastic. For the values given in Table 2, the saturation levels (with no ventilation) are 0.10 ppm, 0.22 ppm, and 0.001 ppm for Undulator A, Wiggler A, and the bending magnet, respectively. Even moderate amounts of ventilation will reduce ozone concentration from undulators and wigglers to very low levels (see below). The concentration levels in the bending-magnet FOEs are two orders of magnitude below any level of concern. Consequently these FOEs require no ventilation for ozone removal.

Ozone Concentrations with Ventilation

White Beam Directly into Air

The results given above show that for white-beam-in-air situations ventilation is needed in experimental stations. To reach a saturation level of 0.05 ppm for an Undulator A beam with a 10-cm air path, a β of 0.75 is needed. For a 50 m^3 station volume this requires a removal rate of 35.7 m^3/s (75,613 cfm). To reach the TLV-STEL level of 0.2 ppm a β of 0.19 is needed, requiring

a removal rate of 9.5 m^3/s (20,121 cfm). Both removal rate values are unrealistic. It is clear from this result that local ventilation must be used.

The effective volume that is being exhausted must be reduced significantly. This is a common technique in industrial hygiene and has been used successfully at other synchrotron facilities.[13] The amount of removal needed scales with the effective volume. Hence, an effective volume of one m^3 requires a removal capacity of 0.75 m^3/s (1589 cfm) for a concentration of 0.05 ppm or a removal capacity of 0.19 m^3/s (402 cfm) for a concentration of 0.2 ppm. The removal rate for the 0.05 ppm level is still rather high, but the rate for the 0.2 ppm level is achievable. If the ozone concentration level for the entire 50 m^3 station is 0.2 ppm, a 0.19 m^3/s removal rate will reduce the level to 0.05 ppm in less than six minutes. This is well under the time limit for a TLV-STEL exposure. (The limit of four TLV-STEL exposures per day, each separated by at least one hour, still applies.)

For the situation given above, the Wiggler A beam (10-cm air path) requires a β of 0.95 for 0.05 ppm ozone and a β of 0.24 for 0.2 ppm ozone. The wiggler beam removal requirements are somewhat higher, but similar to those for the undulator. The bending magnet (10-cm air path) values are a β of 0.06 for 0.05 ppm ozone and a β of 0.015 for 0.2 ppm ozone. The bending magnet removal rates are still high enough that local exhaustion is required, but may allow for less strident methods in reducing the effective volume. A summary of the example calculation results are given in Table 3.

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[13]N. Gmür, L. Berman, M. Iarocci, and C. Weilandics, "Controlling Ozone in White Beam Hutches," NSLS Technical Note 435 (1991).

Table 3. Ventilation Rates for a White Beam in 10 cm of Air

Source	Saturation Levels	β	Effective Volume	Removal Rate	
	ppm	s^{-1}	m^3	m^3/s	cfm
Undulator A	0.05	0.75	50	35.7	75,613
Undulator A	0.2	0.19	50	9.5	20,121
Undulator A	0.05	0.75	1	0.75	1589
Undulator A	0.2	0.19	1	0.19	402
Wiggler A	0.05	0.95	1	0.95	2012
Wiggler A	0.2	0.24	1	0.24	508
Bend. Mag.	0.05	0.06	1	0.06	127
Bend. Mag.	0.2	0.015	1	0.015	32

The size of the effective volume is strongly dependent on the arrangement of a particular experiment. If it is possible to get an air-removal spout close to the entire length of the air path, it should be possible to have effective volumes considerably smaller than one m^3. In this case, the air flow rate may be relatively low. If, on the other hand, there is nonstationary equipment near the air path (e.g., a diffractometer), it may be difficult to get a removal spout near the beam. In this case, it may be more effective to build a shroud around the experiment and have enough negative pressure inside the shroud to prevent the ozone from reaching the rest of the experimental station. In all cases, it is important to have to shortest beam-in-air path possible.

Scattered Radiation

Ozone produced by a scattered beam from Wiggler A can be kept to 0.05 ppm with a β of 0.0012 (assuming a 50 m^3 FOE). A removal capacity of 0.06 m^3/s (127 cfm) will adequately ventilate the entire station volume to the TLV-TWA level. The is only 4.32 air exchanges per hour, which is a very modest

exchange rate. To achieve 0.05 ppm ozone for Undulator A requires a β of 0.0004, with a corresponding removal capacity of 0.02 m^3/s (42 cfm).

Ozone Disposal

The ozone removed from an FOE or experimental station must be appropriately disposed. There are two choices for disposal: to ventilate into the Experiment Hall, or to ventilate to the atmosphere outside of the Experiment Hall. In either case, the exhausted air may be passed through activated carbon filters to reduce the ozone concentration.

For the Experiment Hall, the TLV-TWA levels must be adjusted for likely worker shift durations. A shift of 16 hours per day and 80 hours per week will be assumed. The corresponding TLV-TWA for the Experiment Hall becomes 0.025 ppm of ozone.

The first case to be considered will be the ozone from the scattered beams in FOEs. For simplicity, it will be assumed that there are 34 wiggler white beams generating ozone at 410 $\mu g/min$* and that there is complete mixing of air in the Experiment Hall. This will be a total ozone production of 0.014 g/min. The Experimental Hall has a volume of approximately 84,000 m^3 (3 x 10^6 ft^3). With no ventilation, the saturation level is 0.0045 ppm ozone. This is 20% of the TLV-TWA and should be acceptable. The FOEs can be vented directly into the Experiment Hall.

The capacity for producing ozone from white beam experimental stations is much higher. If just one station has an Undulator A beam in 10 cm of air, it produces 0.215 g/min. If vented directly into the Experiment Hall a saturation level of 0.07 ppm will occur (using the entire Experiment Hall volume), which is higher than the TLV-TWA. With effective carbon filtration, this value can be reduced by approximately 90%, but is still higher than would be acceptable if several stations were producing ozone simultaneously. It is recommended that the ozone produced in insertion-device stations by white beam in air be vented directly (without filtration) to outside the Experiment Hall.

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* This is a worst-case calculation. It is currently estimated that there will be five wigglers (out of a total of 16 insertion devices) during the first phase of APS operation.

For a bending-magnet experimental station the production levels are low enough to allow for options. Thirty-four bending magnet stations, each with 10 cm of white beam in air, will produce enough ozone to have a Experiment Hall level of 0.19 ppm. With 90% effective filtration, this can be reduced to 0.019 ppm, which would be within the TLV-TWA guidelines. Since it is unlikely that there will ever be 34 bending-magnet white-beam stations operating simultaneously, the actual concentration of ozone in the Experiment Hall would probably be considerably lower than 0.019 ppm. For bending-magnet stations with a white-beam-in-air path there are two recommended options: vent directly to the air outside of the Experiment Hall, or use carbon filtration and vent into the Experiment Hall. In the latter case, a the amount of ozone in the exhaust after filtration should not exceed 0.00172 g/min. This level will be checked by the APS.

Maximum Ozone Emission from the APS Experiment Hall

The maximum amount of ozone that could be produced in the Experiment Hall and released into the atmosphere was calculated with the following assumptions:

1. There are 35 Wiggler A experimental stations.
2. There are 35 bending-magnet experimental stations.
3. In each station, a white beam travels through 10 cm of air.
4. All 70 stations are operated for 24 hours per day, 280 days per year (6720 hours/year).
5. All of the ozone produced in the stations is vented to the atmosphere outside of the APS Experiment Hall.

These assumptions give an ozone production rate of 10.26 g/min for all the stations together. The specified number of hours gives a maximum production of 4137 kg of ozone per year from the APS Experiment Hall. The assumptions are very conservative. The actual amount of ozone released to the atmosphere will be far lower.

General Practices to Reduce Ozone Production

Several operating practices will help to keep the ozone production to a minimum. These should be followed even when the ozone concentrations are below acceptable levels.

All beam-in-air paths should be kept to a minimum.

The effective evacuation volumes should be made as small as possible.

If the experiment is conducted at sufficiently high energies, low energy photons can be absorbed in a filter rather than in the air.

For ozone produced by scattered radiation, a small amount of shielding around the scattering point may reduce the energy in the scattered beam significantly.

APS Ozone Mitigation Policy

The following are required by the APS as means to achieve adequate ozone protection for personnel:

1. The APS shall abide by applicable ACGIH TLV guidelines for ozone. Personnel should not enter a station when the ozone level is above the TLV-STEL for any length of time.

2. The TLV-TWA for the Experiment Hall shall be 0.025 ppm of ozone. (A 16-hour day and 80-hour work week were used to determine this level.)

3. First optical enclosures (FOEs) shall have adequate ventilation to ensure that the build up of ozone due to scattered white beam is not above 0.05 ppm.

4. Experimental stations capable of having white beam in air shall have an ozone monitor that produces an audible tone when the station is capable of personnel entry and the ozone concentration is above an APS-specified level

5. Insertion-device experimental stations capable of white beam in air shall have a local ventilation system that vents directly to the outside of the Experiment Hall. An air flow switch shall be used to monitor air flow in the ventilation system. This switch shall be part of the personnel-safety system for the station.

6. Bending magnet experimental stations capable of white beam in air shall have a local ventilation system that either vents directly to the outside of the Experiment Hall or vents into the Experiment Hall after adequate filtering to reduce its ozone emission to no more than 0.0017 g/min of ozone. An air flow switch shall be used to monitor air flow in the ventilation system. This switch shall be part of the personnel-safety system for the station.

Appendix A

Today

Committee Chairs and Board Meet — New Partnership Guide Introduced

In order to form a more perfect partnership between the Board of Directors and the ACGIH Committees, a Joint Meeting of the Committee Chairs and Board Members was recently held at ACGIH headquarters. Among a number of relevant conclusions and planned enhancements was a clear desire for more members to volunteer to serve on Committees within their area of expertise.

"While there are not enough seats on ACGIH Committees to allow every Member or even a large percentage of the Members to serve, the Board continually seeks offers to volunteer on a Committee from qualified individuals. The technical committees, in particular, have tapped the expertise of the Members and, in large measure, the products of these Committees account for ACGIH's reputation and success," noted ACGIH Chair John Martonik.

Current ACGIH Committees are:

- Agricultural Health and Safety
- Air Sampling Instruments
- Air Sampling Procedurea
- Awards
- Bioaerosols
- Biological Exposure Indices
- Computers in Safety and Health
- Construction
- Editorial Review Board
- Finance
- Hazardous Waste
- Industrial Ventilation
- Infectious Diseases
- Membership
- Mining Safety and Health
- Nominating
- Permanent Conference Committee (PCC)
- Professional Regulation Steering Committee (PRSC)
- Research Needs in Industrial Hygiene
- Small Business
- TLV's for Chemical Substances
- TLV's for Physical Agents

Members wishing to serve should write to Mr. Martonik at ACGIH headquarters. Name the Committee for which you are volunteering and be sure to include your Curriculum Vitae.

During the recent meeting, the Committee Chairs reviewed the newly introduced "ACGIH PARTNERSHIP GUIDE: A Reference Manual for Committees" which had been assembled for their use by the Board of Directors. The "PARTNERSHIP GUIDE" is an extensive document in thirteen sections providing guidance and policies for use by all Committees in an effort to make them more efficient and to make service on a Committee more productive, more rewarding, and more enjoyable.

Committee Chairs offered several suggestions for improving the "PARTNERSHIP GUIDE" which the Board will now consider. Committee Chairs were charged with drafting a Mission Statement for the work of their Committees and an Annual Work Plan with more specific details of its goals and activities.

As the "heart and soul" of ACGIH, the Committees and all of their Members were recognized by the Board with thanks for the countless hours and volumes of work they produce for the benefit of all ACGIH Members and for the protection of workers throughout the world.

INSIDE ACGIH Today

Newsletter of the American Conference of Governmental Industrial Hygienists

Rajhans, Vice Chair of the Industrial Ventilation Committee, and Jerry Sherwood, Acting Chair of the Biological Exposure Indices Committee were two of the 18 Committee Chairs at the March meeting.

1993–1994

Threshold Limit Values

for Chemical Substances

and Physical Agents

and

Biological Exposure Indices

ACGIH

INTRODUCTION TO THE CHEMICAL SUBSTANCES

Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness. Smoking of tobacco is harmful for several reasons. Smoking may act to enhance the biological effects of chemicals encountered in the workplace and may reduce the body's defense mechanisms against toxic substances.

Individuals may also be hypersusceptible or otherwise unusually responsive to some industrial chemicals because of genetic factors, age, personal habits (smoking, alcohol, or other drugs), medication, or previous exposures. Such workers may not be adequately protected from adverse health effects from certain chemicals at concentrations at or below the threshold limits. An occupational physician should evaluate the extent to which such workers require additional protection.

TLVs are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance, or other forms of stress may form the basis for others.

The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the precision of the estimated TLV is also subject to variation and the latest TLV *Documentation* should be consulted in order to assess the extent of the data available for a given substance.

These limits are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use, e.g., in the evaluation or control of community air pollution nuisances; in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods; as proof or disproof of an existing disease or physical condition; or adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ. These limits *are not* fine lines between safe and dangerous concentration nor are they a relative index of toxicity. They *should not* be used by anyone untrained in the discipline of industrial hygiene.

The TLVs, as issued by the American Conference of Governmental Industrial Hygienists, are recommendations and should be used as guidelines for good practices. In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

The American Conference of Governmental Industrial Hygienists disclaims liability with respect to the use of TLVs.

Notice of Intended Changes. Each year, proposed actions of the Chemical Substances TLV Committee for the forthcoming year are issued in the form of a "Notice of Intended Changes." This Notice provides an opportunity for comment and *solicits suggestions of substances to be added to the list. The suggestions should be accompanied by substantiating evidence.* The "Notice of Intended Changes" is presented after the Adopted Values in this section. Values listed in parentheses in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Definitions. Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value–Time-Weighted Average (TLV–TWA)—the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value–Short-Term Exposure Limit (TLV–STEL)—the concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV–TWA is not exceeded. It is not a separate independent exposure limit; rather, it supplements the time-weighted average (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15-minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the TLV–TWA. Exposures above the TLV–TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

c) Threshold Limit Value–Ceiling (TLV–C)—the concentration that should not be exceeded during any part of the working exposure.

In conventional industrial hygiene practice if instantaneous monitoring is not feasible, then the TLV–C can be assessed by sampling over a 15-minute period except for those substances that may cause immediate irritation when exposures are short.

For some substances, e.g., irritant gases, only one category, the TLV–Ceiling, may be relevant. For other substances, one or two categories may be relevant, depending upon their physiologic action. It

is important to observe that if any one of these types of TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The Chemical Substances TLV Committee holds to the opinion that TLVs based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote, or accelerate physical impairment through interaction with other chemical or biologic agents.

Time-Weighted Average (TWA) vs Ceiling (C) Limits. TWAs permit excursions above the TLV provided they are compensated by equivalent excursions below the TLV–TWA during the workday. In some instances, it may be permissible to calculate the average concentration for a workweek rather than for a workday. The relationship between the TLV and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which the TLVs may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations—even for short periods—produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All factors must be taken into consideration in arriving at a decision as to whether a hazardous condition exists.

Although the TWA concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the TLVs, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose TLV is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling limit that should not be exceeded. It is implicit in these definitions that the manner of sampling to determine noncompliance with the limits for each group must differ; a single, brief sample, that is applicable to a ceiling limit, is not appropriate to the TWA; here, a sufficient number of samples are needed to permit a TWA concentration throughout a complete cycle of operations or throughout the workshift.

Whereas the ceiling limit places a definite boundary that concentrations should not be permitted to exceed, the TWA requires an explicit limit to the excursions that are permissible above the listed TLVs. It should be noted that the same factors are used by the Chemical Substances TLV Committee in determining the magnitude of the value of the STEL or whether to include or exclude a substance for a ceiling listing.

Excursion Limits. For the vast majority of substances with a TLV–TWA, there is not enough toxicological data available to warrant a STEL. Nevertheless, excursions above the TLV–TWA should be controlled even where the 8-hour TLV–TWA is within recommended limits. Earlier editions of the TLV list included such limits whose values depended on the TLV–TWAs of the substance in question.

While no rigorous rationale was provided for these particular values, the basic concept was intuitive: in a well-controlled process exposure, excursions should be held within some reasonable limits. Unfortunately, neither toxicology nor collective industrial hygiene

experience provide a solid basis for quantifying what those limits should be. The approach here is that the maximum recommended excursion should be related to variability generally observed in actual industrial processes. In reviewing large numbers of industrial hygiene surveys conducted by the National Institute for Occupational Safety and Health, Leidel, Busch, and Crouse[1] found that short-term exposure measurements were generally lognormally distributed with geometric standard deviations mostly in the range of 1.5 to 2.0.

While a complete discussion of the theory and properties of the lognormal distribution is beyond the scope of this section, a brief description of some important terms is presented. The measure of central tendency in a lognormal description is the antilog of the mean logarithm of the sample values. The distribution is skewed, and the geometric mean is always smaller than the arithmetic mean by an amount which depends on the geometric standard deviation. In the lognormal distribution, the geometric standard deviation (sd_g) is the antilog of the standard deviation of the sample value logarithms and 68.26% of all values lie between m_g/sd_g and $m_g \times sd_g$.

If the short-term exposure values in a given situation have a geometric standard deviation of 2.0, 5% of all values will exceed 3.13 times the geometric mean. If a process displays a variability greater than this, it is not under good control and efforts should be made to restore control. This concept is the basis for the following excursion limit recommendations which apply to those TLV–TWAs that do not have STELs:

> *Excursions in worker exposure levels may exceed 3 times the TLV–TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV–TWA, provided that the TLV–TWA is not exceeded.*

The approach is a considerable simplification of the idea of the lognormal concentration distribution but is considered more convenient to use by the practicing industrial hygienist. If exposure excursions are maintained within the recommended limits, the geometric standard deviation of the concentration measurements will be near 2.0 and the goal of the recommendations will be accomplished.

When the toxicological data for a specific substance are available to establish a STEL, this value takes precedence over the excursion limit regardless of whether it is more or less stringent.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential significant contribution to the overall exposure by the cutaneous route, including mucous membranes and the eyes, either by contact with vapors or, of probable greater significance, by direct skin contact with the substance. Vehicles present in solutions or mixtures can also significantly enhance potential skin absorption. It should be noted that while some materials are capable of causing irritation, dermatitis, and sensitization in workers, these properties are *not considered relevant* when assigning a skin notation. It should be noted, however, that the development of a dermatological condition can significantly affect the potential for dermal absorption.

While limited quantitative data currently exist with regard to skin absorption of gases, vapors, and liquids by workers, the Chemical Substances TLV Committee recommends that the integration of data from acute dermal studies and repeated dose dermal studies in animals and/or humans, along with the ability of the chemical to be absorbed, be used in deciding on the appropriateness of the skin notation. In general, available data which suggest that the potential for absorption via the hands/forearms during the workday could be significant, especially for chemicals with lower TLVs, could justify a skin notation. From acute animal toxicity data, materials having a relatively low dermal LD_{50} (1000 mg/kg of body weight or less) would be given a skin notation. Where repeated dermal application studies have shown significant systemic effects following treatment, a skin notation would be considered. When chemicals penetrate the skin easily (higher octanol–water partition coefficients) and where extrapolations of systemic effects from other routes of exposure suggest dermal absorption may be important in the expressed toxicity, a skin notation should be considered.

Substances having a skin notation and a low TLV may present special problems for operations involving high airborne concentrations of the material, particularly under conditions where significant areas of the skin are exposed for a long period of time. Under these conditions, special precautions to significantly reduce or preclude skin contact may be required.

Biological monitoring should be considered to determine the relative contribution of exposure via the dermal route to the total dose. The TLV/BEI Booklet contains a number of adopted biological exposure indices, which provide an additional tool when assessing the worker's total exposure to selected materials.

Use of the skin designation is intended to alert the reader that air sampling alone is insufficient to accurately quantitate exposure and that measures to prevent significant cutaneous absorption may be required.

Mixtures. Special consideration should be given also to the application of the TLVs in assessing the health hazards that may be associated with exposure to mixtures of two or more substances. A brief discussion of basic considerations involved in developing TLVs for mixtures and methods for their development, amplified by specific examples, are given in Appendix C.

Respirable and Total Dust. For solid substances and liquified mists, TLVs are expressed in terms of total dust, except where the term "respirable dust" is used. See Appendix D, Particle Size-Selective Sampling Criteria for Airborne Particulate Matter, for the definition of respirable dust (respirable particulate mass).

Particulates Not Otherwise Classified (PNOC). In contrast to fibrogenic dusts which cause scar tissue to be formed in lungs when inhaled in excessive amounts, so-called "nuisance" dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. Such dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung when inhaled in sufficient amount. However, the lung-tissue reaction caused by inhalation of PNOCs has the following characteristics: 1) the architecture of the air spaces remains intact; 2) collagen (scar tissue) is not formed to a significant extent; and 3) the tissue reaction is potentially reversible.

Excessive concentrations of PNOCs in the workroom air may seriously reduce visibility; may cause unpleasant deposits in the eyes, ears, and nasal passages (e.g., Portland cement dust); or cause injury to the skin or mucous membranes by chemical or mechanical action per se or by the rigorous skin cleansing procedures necessary for their removal.

A TLV–TWA of 10 mg/m^3 of total dust containing no asbestos and < 1% crystalline silica is recommended for substances in these categories and for which no specific TLVs have been assigned. This value, for a normal work day, does not apply to brief exposures at higher concentrations. Neither does it apply to those substances which may cause physiologic impairment at lower concentrations but for which a TLV has not yet been adopted.

Simple Asphyxiants—"Inert" Gases or Vapors. A number of gases and vapors, when present in high concentrations in air, act primarily as simple asphyxiants without other significant physiologic effects. A TLV may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. The minimal oxygen content should be 18% by volume under normal atmospheric pressure (equivalent to a partial pressure, pO_2 of 135 torr). Atmospheres deficient in O_2 do not provide adequate warning and most simple asphyxiants are odorless. Several simple asphyxiants present an explosion hazard. Account should be taken of this factor in limiting the concentration of the asphyxiant.

Biological Exposure Indices (BEI). A cross reference is indicated for those substances for which there are also Biological Exposure Indices. For such substances, biological monitoring should be instituted to evaluate the total exposure, e.g., dermal, ingestion, or nonoccupational. See the BEI section in this Booklet.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing radiation, humidity, abnormal pressure (altitude), and the like may place added stress on the body so that the effects from exposure at a TLV may be altered. Most of these stresses act adversely to increase the toxic response of a substance. *Although most TLVs have built-in safety factors to guard against adverse effects to moderate deviations* from normal environments, the safety factors of most substances are not of such a magnitude as to take care of gross deviations. For example, continuous work at temperatures above 32°C (90°F), or overtime extending the workweek more than 25%, might be considered gross deviations. In such instances, judgment must be exercised in the proper adjustments of the TLVs.

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of

instances, the material is rarely present as a particulate, vapor, or other airborne contaminant, and a TLV is not necessary. In other cases, sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Chemical Substances TLV Committee.

Unusual Work Schedules. Application of TLVs to workers on work schedules markedly different from the conventional 8-hour day, 40-hour week requires particular judgement in order to provide, for such workers, protection equal to that provided to workers on conventional workshifts.

As tentative guidance, field hygienists are referred to the "Brief and Scala model" which is described and explained at length in Patty.[2]

The Brief and Scala model reduces the TLV proportionately for both increased exposure time and reduced recovery (nonexposure) time. The model is generally intended to apply to work schedules longer than 8 hours/day or 40 hours/week. The model should not be used to justify very high exposures as "allowable" where the exposure periods are short (e.g., exposure to 8 times the TLV–TWA for one hour and zero exposure during the remainder of the shift). In this respect, the general limitations on TLV excursions and STELs should be applied to avoid inappropriate use of the model with very short exposure periods or shifts.

Since adjusted TLVs do not have the benefit of historical use and long-time observation, medical supervision during initial use of adjusted TLVs is advised. In addition, the hygienist should avoid unnecessary exposure of workers even if a model shows such exposures to be "allowable" and should not use models to justify higher-than-necessary exposures.

The Brief and Scala model is easier to use than some of the more complex models based on pharmacokinetic actions. However, hygienists thoroughly familiar with such models may find them more appropriate in specific instances. Use of such models usually requires knowledge of the biological half-life of each substance, and some models require additional data.

Short workweeks can allow workers to have two full-time jobs, perhaps with similar exposures, and may result in overexposure even if neither job by itself entails overexposure. Hygienists should be alert to such situations.

Conversion of TLVs in ppm to mg/m³. TLVs for gases and vapors are usually established in terms of parts per million of substance in air by volume (ppm). For convenience to the user, these TLVs are also listed here in terms of milligrams of substance per cubic meter of air (mg/m^3). The conversion is based on 760 torr barometric pressure at 25°C (77°F), and where 24.45 = molar volume in liters, giving a conversion equation of:

$$\text{TLV in mg/m}^3 = \frac{(\text{TLV in ppm})\ (\text{gram molecular weight of substance})}{24.45}$$

Conversely, the equation for converting TLVs in mg/m^3 to ppm is:

$$\text{TLV in ppm} = \frac{(\text{TLV in mg/m}^3)\ (24.45)}{(\text{gram molecular weight of substance})}$$

Resulting values are rounded to two significant figures below 100 and to three significant figures above 100. This is not done to give any converted value a greater precision than that of the original TLV, but to avoid increasing or decreasing the TLV significantly merely by the conversion of units.

The above equation may be used to convert TLVs to any degree of precision desired. When converting TLVs to mg/m^3 units for other temperatures and pressures, the reference TLVs should be used as a starting point. When converting values expressed as an element (e.g., as Fe, as Ni), the molecular value of the element should be used, not that of the entire compound.

In making conversions for substances with variable molecular weights, appropriate molecular weights have been estimated or assumed (see the TLV *Documentation*).

Biologically-derived Airborne Contaminants. The ACGIH Bioaerosols Committee has developed Guidelines for evaluating biological-source air contaminants in indoor environments (*Guidelines for the Assessment of Bioaerosols in the Indoor Environment*, ACGIH, 1989). The Guidelines rely on medical assessment of symptoms, evaluation of building performance, and professional judgement. For the reasons identified in the following, there are no numerical guidelines or TLVs that allow ready interpretation of bioaerosol data and routine sampling for bioaerosols is not recommended. If sampling is necessary (e.g., to document the contribution of identified sources), standard protocols are recommended in the Guidelines.

Biologically derived airborne contaminants include bioaerosols (airborne particulates composed of or derived from living organisms) and volatile organic compounds released from living organisms. Bioaerosols include microorganisms (culturable, nonculturable, and dead microorganisms) and fragments, toxins, and particulate waste products from all varieties of living things. Biologically derived airborne contaminant mixtures are ubiquitous in nature and may be modified by human activity. All persons are repeatedly exposed, day after day, to a wide variety of such contaminants. At present, gravimetric Threshold Limit Values (TLVs) exist for some wood dusts, which are primarily of biological origin, and for cotton dust, which is at least in part biological. There are no TLVs for concentrations of total culturable or countable organisms and particles (e.g., "bacteria" or "fungi"); specific culturable or countable organisms and particles (e.g., *Aspergillus fumigatus*); infectious agents (e.g., *Legionella pneumophila*; or assayable biological-source contaminants (e.g., endotoxin or volatile organic compounds).

A. A general TLV for a concentration of culturable (e.g., total bacteria and/or fungi) or countable bioaerosols (e.g., total pollen, fungal spores, and bacteria) is not scientifically supportable because:

1. Culturable organisms or countable spores do not comprise a single entity, i.e., bioaerosols are complex mixtures of different kinds of particles.
2. Human responses to bioaerosols range from innocuous effects to serious disease and depend on the specific agent and susceptibility factors within the person.
3. Measured concentrations of culturable and countable bioaerosols are dependent on the method of sample collection and analysis. It is not possible to collect and evaluate all of these bioaerosol components using a single sampling method.

B. Specific TLVs for individual culturable or countable bioaerosols, established to prevent irritant, toxic, or allergic responses have not been established. At present, information relating culturable or countable bioaerosol concentrations to irritant, toxic, or allergic responses consists largely of case reports containing only qualitative exposure data. The epidemiologic data that exist are insufficient to describe exposure–response relationships. Reasons for the absence of good epidemiologic data on exposure–response relationships include:

1. Most data on concentrations of specific bioaerosols are derived from indicator measurements rather than from measurement of actual effector agents. For example, culturable fungi are used to represent exposure to allergens. In addition, most measurements are either from reservoir or from ambient air samples. These approaches are unlikely to accurately represent human exposure to actual effector agents.
2. The components and concentrations of bioaerosols vary widely. The most commonly used air sampling devices collect only "grab" samples over short periods of time and these single samples may not represent human exposure. Short-term grab samples may contain an amount of a particular bioaerosol that is orders of magnitude higher or lower than the average environmental concentration. Some organisms release aerosols as "concentration bursts" and can be detected only rarely using grab samples. Yet, such episodic bioaerosols may produce significant health effects.

C. Dose–response data are available for some infectious bioaerosols. At present, air sampling protocols for infectious agents are limited and suitable only for research endeavors. Traditional public health methods, including immunization, active case finding, and medical treatment, remain the primary defenses against infectious bioaerosols. Certain public and medical facilities with high risk for transmission of infection (e.g., tuberculosis) should employ exposure controls to reduce possible airborne concentrations of virulent and opportunistic pathogens.

D. Assayable, biologically derived contaminants are substances produced by living things that can be detected using either chemical, immunological, or biological assay and include endotoxin, mycotoxins, allergens, and volatile organic compounds. Evidence does not yet support TLVs for any of the assayable substances. Assay methods for certain common aeroallergens and endotoxin are steadily improving. Also, innovative molecular techniques are rendering assayable the concentration of specific organisms currently detected only by culture or counting. Dose–response relationships for some assayable bioaerosols have been observed in experimental studies and occasionally in epidemiologic studies. Validation of these assays in the field is also progressing.

The ACGIH Bioaerosols Committee actively solicits information, comments, and especially data that will assist it in evaluating the role of bioaerosols in the environment.

Operational Guidelines. The ACGIH Board of Directors has adopted Operational Guidelines and Procedures for the Chemical Substances TLV Committee. These guidelines prescribe: charge, authority, policies, membership, organization, and operating procedures. The policies include the appeals procedures.

References

1. Leidel, N.A.; Busch, K.A.; Crouse, W.E.: Exposure Measurement, Action Level and Occupational Environmental Variability. DHEW (NIOSH) Pub. No. 76-131 (December 1975).
2. Paustenbach, D.J.: Occupational Exposure Limits, Pharmacokinetics, and Unusual Work Schedules. In: Patty's Industrial Hygiene and Toxicology, 2nd ed., Vol. 3A, The Work Environment, Chap. 6, pp. 111–277. L.J. Cralley and L.V. Cralley, Eds. John Wiley and Sons, Inc., New York (1985).

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
‡•■4,4'-Methylene bis (2-chloroaniline) [MOCA] [101-14-4]—Skin (1993)	0.01,A2	0.11,A2	—	—
Methylene bis(4-cyclo-hexylisocyanate) [5124-30-1] (1988)	0.005	0.054	—	—
■ 4,4'-Methylene dianiline [101-77-9]—Skin (1986)	0.1,A2	0.81,A2	—	—
◄ Methyl ethyl ketone (MEK) [78-93-3] (1976)	200	590	300	885
Methyl ethyl ketone peroxide [1338-23-4] (1977)	C 0.2	C 1.5	—	—
Methyl formate [107-31-3] (1976)	100	246	150	368
5-Methyl-3-heptanone, *see* Ethyl amyl ketone				
‡•■ Methyl hydrazine [60-34-4]—Skin (1976)	(C 0.2,A2)	(C 0.38,A2)	—	—
■ Methyl iodide [74-88-4]—Skin (1986)	2,A2	12,A2	—	—
Methyl isoamyl ketone [110-12-3] (1982)	50	234	—	—
Methyl isobutyl carbinol [108-11-2]—Skin (1976)	25	104	40	167
◄ Methyl isobutyl ketone [108-10-1] (1981)	50	205	75	307
Methyl isocyanate [624-83-9]—Skin (1977)	0.02	0.047	—	—
Methyl isopropyl ketone [563-80-4] (1981)	200	705	—	—
• Methyl mercaptan [74-93-1] (1977)	0.5	0.98	—	—
Methyl methacrylate [80-62-6] (1987)	100	410	—	—
◄ Methyl parathion [298-00-0]—Skin (1986)	—	0.2	—	—
• Methyl propyl ketone [107-87-9] (1976)	200	705	250	881
Methyl silicate [681-84-5] (1986)	1	6	—	—
α-Methyl styrene [98-83-9] (1981)	50	242	100	483
Metribuzin [21087-64-9] (1984)	—	5	—	—
◄ Mevinphos [7786-34-7]—Skin (1976)	0.01	0.092	0.03	0.27
Mica [12001-26-2] (1986)	—	3(f)	—	—
Mineral wool fiber (1974)	—	10(e)	—	—
Molybdenum [7439-98-7], as Mo Soluble compounds (1986)	—	5	—	—
Insoluble compounds (1986)	—	10	—	—
Monochlorobenzene, *see* Chlorobenzene				
Monocrotophos [6923-22-4]—Skin (1977)	—	0.25	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Morpholine [110-91-8]—Skin (1991)	20	71	—	—
◄ Naled [300-76-5]—Skin (1986)	—	3	—	—
Naphthalene [91-20-3] (1976)	10	52	15	79
■ β-Naphthylamine [91-59-8] (1972)	—	A1	—	—
Neon [7440-01-9] (1981)	—(c)	—	—	—
‡■ Nickel [7440-02-0]				
‡Metal (1986)	—	(1)	—	—
‡Insoluble compounds, as Ni (1974)	—	(1)	—	—
‡•■Soluble compounds, as Ni (1976)	—	(0.1)	—	—
‡•■ Nickel carbonyl [13463-39-3], as Ni (1977)	(0.05)	(0.12)	—	—
‡•■ Nickel sulfide roasting, fume & dust, as Ni (1978)	—	(1,A1)	—	—
Nicotine [54-11-5]—Skin (1986)	—	0.5	—	—
Nitrapyrin [1929-82-4] (1982)	—	10	—	20
Nitric acid [7697-37-2] (1976)	2	5.2	4	10
◄ Nitric oxide [10102-43-9] (1986)	25	31	—	—
◄ p-Nitroaniline [100-01-6]—Skin (1982)	—	3	—	—
◄ Nitrobenzene [98-95-3]—Skin (1986)	1	5	—	—
◄■ p-Nitrochlorobenzene [100-00-5]—Skin (1988)	0.1	0.64	—	—
■ 4-Nitrodiphenyl [92-93-3]—Skin (1976)	—	A1	—	—
Nitroethane [79-24-3] (1986)	100	307	—	—
Nitrogen [7727-37-9] (1989)	—(c)	—	—	—
• Nitrogen dioxide [10102-44-0] (1981)	3	5.6	5	9.4
◄ Nitrogen trifluoride [7783-54-2] (1986)	10	29	—	—
• Nitroglycerin (NG) [55-63-0]—Skin (1985)	0.05	0.46	—	—
‡ Nitromethane [75-52-5] (1986)	(100)	(250)	—	—
1-Nitropropane [108-03-2] (1986)	25	91	—	—
■ 2-Nitropropane [79-46-9] (1987)	10,A2	36,A2	—	—
■ N-Nitrosodimethylamine [62-75-9]—Skin (1972)	—	A2	—	—
◄ Nitrotoluene [88-72-2; 99-08-1; 99-99-0] —Skin (1982)	2	11	—	—
Nitrotrichloromethane, *see* Chloropicrin				
Nitrous oxide [10024-97-2] (1989)	50	90	—	—
Nonane [111-84-2], all isomers (1976)	200	1050	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Nuisance particulates, *see* Particulates Not Otherwise Classified (PNOC)				
Octachloronaphthalene [2234-13-1]—Skin (1976)	—	0.1	—	0.3
Octane [111-65-9] (1976)	300	1400	375	1750
‡ Oil Mist, mineral (1976)	—	5[k]	—	(10)
Osmium tetroxide [20816-12-0], as Os (1976)	0.0002	0.0016	0.0006	0.0047
Oxalic acid [144-62-7] (1976)	—	1	—	2
Oxygen difluoride [7783-41-7] (1986)	C 0.05	C 0.11	—	—
‡ Ozone [10028-15-6] (1989)	(C 0.1)	(C 0.20)	(—)	(—)
Paraffin wax fume [8002-74-2] (1987)	—	2	—	—
Paraquat [4685-14-7], total dust (1978)	—	0.5	—	—
respirable fraction (1978)	—	0.1	—	—
◄• Parathion [56-38-2]—Skin (1986)	—	0.1	—	—
Particulate polycyclic aromatic hydrocarbons (PPAH), see Coal tar pitch volatiles				
Particulates Not Otherwise Classified (PNOC) (1989)	—	10[e]	—	—
Pentaborane [19624-22-7] (1976)	0.005	0.013	0.015	0.039
Pentachloronaphthalene [1321-64-8]—Skin (1986)	—	0.5	—	—
Pentachloronitrobenzene [82-68-8] (1991)	—	0.5	—	—
◄• Pentachlorophenol [87-86-5]—Skin (1986)	—	0.5	—	—
Pentaerythritol [115-77-5] (1986)	—	10	—	—
• Pentane [109-66-0] (1976)	600	1770	750	2210
2-Pentanone, *see* Methyl propyl ketone				
*◄•• Perchloroethylene (Tetrachloroethylene) [127-18-4] (1993)	25,A3	170,A3	100,A3	685,A3
Perchloromethyl mercaptan [594-42-3] (1977)	0.1	0.76	—	—
Perchloryl fluoride [7616-94-6] (1976)	3	13	6	25
Perfluoroisobutylene [382-21-8] (1992)	C 0.01	C 0.082	—	—
Precipitated silica, *see* Silica—Amorphous				
Perlite [93763-70-3] (1986)	—	10[e]	—	—
Petroleum distillates, *see* Gasoline; Stoddard solvent; VM&P naphtha				
Phenacyl chloride, *see* α-Chloroacetophenone				
◄ Phenol [108-95-2]—Skin (1987)	5	19	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Phenothiazine [92-84-2]—Skin (1986)	—	5	—	—
▪ N-Phenyl-beta-naphthylamine [135-88-6] (1979)	A2	A2	—	—
o-Phenylenediamine [95-54-5] (1991)	—	0.1,A2	—	—
m-Phenylenediamine [108-45-2] (1991)	—	0.1	—	—
p-Phenylenediamine [106-50-3] (1991)	—	0.1	—	—
Phenyl ether [101-84-8], vapor (1976)	1	7	2	14
Phenylethylene, *see* Styrene, monomer				
‡•▪ Phenyl glycidyl ether (PGE) [122-60-1] (1982)	(1)	(6.1)	—	—
•▪ Phenylhydrazine [100-63-0]—Skin (1991)	0.1,A2	0.44,A 2	—	—
• Phenyl mercaptan [108-98-5] (1978)	0.5	2.3	—	—
Phenylphosphine [638-21-1] (1977)	C 0.05	C 0.23	—	—
Phorate [298-02-2]—Skin (1976)	—	0.05	—	0.2
Phosdrin, *see* Mevinphos				
Phosgene [75-44-5] (1978)	0.1	0.40	—	—
Phosphine [7803-51-2] (1976)	0.3	0.42	1	1.4
Phosphoric acid [7664-38-2] (1976)	—	1	—	3
Phosphorus (yellow) [7723-14-0] (1986)	0.02	0.1	—	—
Phosphorus oxychloride [10025-87-3] (1990)	0.1	0.63	—	—
Phosphorus pentachloride [10026-13-8] (1980)	0.1	0.85	—	—
Phosphorus pentasulfide [1314-80-3] (1976)	—	1	—	3
Phosphorus trichloride [7719-12-2] (1982)	0.2	1.1	0.5	2.8
Phthalic anhydride [85-44-9] (1987)	1	6.1	—	—
m-Phthalodinitrile [626-17-5] (1977)	—	5	—	—
Picloram [1918-02-1] (1990)	—	10	—	—
Picric acid [88-89-1] (1990)	—	0.1	—	—
Pindone [83-26-1] (1987)	—	0.1	—	—
Piperazine dihydrochloride [142-64-3] (1982)	—	5	—	—
2-Pivalyl-1,3-indandione, *see* Pindone				
Plaster of Paris, *see* Calcium sulfate				
Platinum [7440-06-4]				
Metal (1981)	—	1	—	—
Soluble salts, as Pt (1970)	—	0.002	—	—

NOTICE OF INTENDED CHANGES
(for 1993–1994)

These substances, with their corresponding values, comprise those for which either a limit has been proposed for the first time, for which a change in the "Adopted" listing has been proposed, or for which retention on the Notice of Intended Changes has been proposed. In all cases, the proposed limits should be considered trial limits that will remain in the listing for a period of at least one year. If, after one year no evidence comes to light that questions the appropriateness of the values herein, the values will be reconsidered for the "Adopted" list. Documentation is available for each of these substances and their proposed values.

Substance	[CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
† Acetone cyanohydrin	[75-86-5], as CN—Skin	C 4.7	5	—	—
Adiponitrile	[111-69-3]—Skin	2	8.8		
† Ammonium perfluorooctanoate	[3825-26-1]	—	0.01,A3	—	—
Asbestos, all forms	[1332-21-4]	0.2 f/cc,[f]A1		—	—
Benzene	[71-43-2]—Skin	0.1,A1	0.3,A1	—	—
Benzyl acetate	[140-11-4]	10,A3	61,A3	—	—
† Bromine	[7726-95-6]	0.1	0.66	0.2	1.3
† 1,3-Butadiene	[106-99-0]	2,A2	4.4,A2	—	—
n-Butyl acetate	[123-86-4]	20	95	—	—
† Chromium, elemental	[7440-47-3], metal and inorganic compounds, as Cr				
Metal		—	0.5,A4	—	—
Cr III compounds		—	0.5,A4	—	—
Water-soluble Cr VI compounds		—	0.05,A1	—	—
Insoluble Cr VI compounds		—	0.01,A1	—	—
Cobalt, elemental	[7440-48-4], and inorganic compounds, as Co	—	0.02,A3	—	—
† 2-N-Dibutylaminoethanol	[102-81-8]—Skin	0.5	3.5	—	—
† Diethanolamine	[111-42-2]—Skin	0.46	2	—	—
† Diethylamine	[109-89-7]—Skin	5,A4	15,A4	15,A4	45,A4
† 2-Diethylaminoethanol	[100-37-8]—Skin	2	9.6	—	—
† Dimethylethoxysilane	[14857-34-2]	0.5	2.1	1.5	6.4
1,1-Dimethylhydrazine	[57-14-7]—Skin	0.01,A2	0.025,A2	—	—
Epichlorohydrin	[106-89-8]—Skin	0.1,A2	0.38,A2	—	—
† EPN	[2104-64-5]—Skin	—	0.1	—	—
† Ethylamine	[75-04-7]—Skin	5	9.2	15	27.6
† Ethyl chloride	[75-00-3]	100,A3	264	—	—
† Heptachlor and Heptachlor epoxide	[76-44-8]—Skin	—	0.05,A3	—	—

Substance	[CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
† Hexachlorobenzene	[118-74-1]—Skin	—	0.025,A3	—	—
Hydrazine	[302-01-2]—Skin	0.01,A2	0.013,A2	—	—
† Hydrogen cyanide and Cyanide salts, as CN					
Hydrogen cyanide	[74-90-8]—Skin	C 4.7	C 5	—	—
Calcium cyanide	[592-01-8]—Skin	—	C 5	—	—
Potassium cyanide	[151-50-8]—Skin	—	C 5	—	—
Sodium cyanide	[143-33-9]—Skin	—	C 5	—	—
† Lead, elemental	[7439-92-1], and inorganic compounds, as Pb*	—	0.05,A3	—	—
Manganese, elemental	[7439-96-5], and inorganic compounds, as Mn	—	0.2	—	—
† Mercury, as Hg—Skin					
Alkyl compounds		—	0.01	—	0.03
Aryl compounds		—	0.1	—	—
Elemental	[7439-97-6] and inorganic compounds including Hg vapor	—	0.025,A4	—	—
† Methyl-tert butyl ether	[1634-04-4]	40	144	—	—
Methyl hydrazine	[60-34-4]—Skin	0.01,A2	0.019,A2	—	—
Nickel, elemental	[7440-02-0], insoluble and soluble compounds, as Ni	—	0.05,A1	—	—
Nickel carbonyl	[13463-39-3], as Ni	Delete listing; included in listing for Nickel, elemental, insoluble and soluble compounds			
Nickel sulfide roasting, fume & dust, as Ni		Delete listing; included in listing for Nickel, elemental, insoluble and soluble compounds			
Nitromethane	[75-52-5]	20	50	—	—
† Oil Mist, mineral					
Severely refined		—	5[k]	—	—
Mildly refined, as cyclohexane soluble particulate containing polynuclear aromatic hydrocarbons (PNAs)		—	0.2[k],A1	—	—
† Ozone	[10028-15-6]	0.05	0.1	0.2	0.4
† Phenyl glycidyl ether (PGE)	[122-60-1]—Skin	0.1,A3	0.6,A3	—	—
† Sodium fluoroacetate (previously listed as Sodium perfluoroacetate)	[62-74-8]—Skin	—	0.05	—	—
† Sulfometuron methyl	[74222-97-2]	—	5,A4	—	—
† Triethylamine	[121-44-8]—Skin	1	4.1	5	20.7

*Blood Pb should be controlled to a value at or below 20 µg/dl (see TLV Documentation for Lead, elemental, and inorganic compounds).

NOTES

ADVANCED
EXPERIMENTAL

FOOTNOTES

- 1993-1994 Adoption
- ‡ See Notice of Intended Changes
- ( ) Adopted values enclosed are those for which changes are proposed. Consult the Notice of Intended Changes for current proposal.
- † 1993–1994 Revision or Addition to the Notice of Intended Changes.
- ◄ Identifies substances for which there are also BEIs (see BEI section). Substances identified in the BEI documentations for methemoglobin inducers (for which methemoglobin is the principle toxicity) and organophosphorus cholinesterase inhibitors are part of this notation.
- • Substance for which the TLV is higher than the OSHA Permissible Exposure Limit (PEL) and/or the NIOSH Recommended Exposure Limit (REL). See CFR 58(124): 36338–33351, June 30, 1993, for revised OSHA PELs.
- ■ Substance identified by other sources as a suspected or confirmed human carcinogen.
- A Refers to Appendix A — Carcinogens.
- B Refers to Appendix B — Substances of Variable Composition.
- C Denotes Ceiling limit.
- (a) Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 torr.
- (b) Milligrams of substance per cubic meter of air.
- (c) Simple asphyxiant; see definition in the "Introduction to the Chemical Substances."
- (d) NOC = not otherwise classified.
- (e) The value is for total dust containing no asbestos and < 1% crystalline silica.
- (f) Fibers longer than 5 μm and with an aspect ratio equal to or greater than 3:1 as determined by the membrane filter method at 400–450X magnification (4-mm objective) phase contrast illumination.
- (g) The value is for dust containing < 5% crystalline silica. For dust containing more than this percentage of crystalline silica, the environment should be evaluated against the TLV–TWA of 0.1 mg/m^3 for respirable quartz. The concentration of respirable dust for the application of this limit is to be determined from the fraction passing a size-selector with the characteristics define d in the "c." paragraphs of Appendix D.
- (h) Lint-free dust as measured by the vertical elutriator cotton-dust sampler described in the Transactions of the National Conference on Cotton Dust, p. 33, by J.R. Lynch (May 2, 1970).
- (i) Total dust/particulate.
- (j) These TLVs are for the respirable fraction of dust (respirable particulate mass) for the substance listed. The concentration of respirable dust for the application of this limit is to be determined from the fraction passing a size-selector with the characteristics defined in the "c." paragraphs of Appendix D.
- (k) As sampled by method that does not collect vapor.
- (l) Does not include stearates of toxic metals.
- (m) Based on "high-volume" sampling.
- (n) However, sho uld not exceed 2 mg/m^3 respirable dust.
- (o) For greater assurance of worker protection, biological monitoring is recommended.
- (p) Except castor, cashew nut, or similar irritant oils.

Annual Reports of the Committees on Threshold Limit Values and Biological Exposure Indices

Chemical Substances TLV Committee

Report to the ACGIH Membership for Approval at the Annual Membership Meeting, May 24, 1994, Anaheim, California.

Notice of Intended Changes for 1994–1995

These substances, with their corresponding values, comprise those for which either a limit has been proposed for the first time, for which a change in the "Adopted" listing has been proposed, or for which retention on the Notice of Intended Changes has been proposed. In all cases, the proposed limits should be considered trial limits that will remain in the listing for a period of at least one year. If, after one year no evidence comes to light that questions the appropriateness of the values herein, the values will be reconsidered for the "Adopted" list. Documentation is available for each of these substances and their proposed values.

	TWA		STEL	
Substance [CAS#]	ppm[a]	mg/m³[b]	ppm[a]	mg/m³[b]
†Acetone [67-64-1]	200, A4	476, A4	400, A4	952, A4
Asbestos, all forms [1332-21-4]	—	0.2 f/cc,[f] A1	—	—
†Benzene [71-43-2] - Skin	0.3, A1	0.96, A1	—	—
†Benzoyl chloride [98-88-4]	C 0.5	C 2.8	—	—
†Benzyl Acetate [140-11-4]	10, A4	61, A4	—	—
†tert-Butanol [75-65-0]	100, A4	303, A4	—	—
n-Butyl acetate [123-86-4]	20	95	—	—
†Dichloroacetylene [7572-29-4]	C 0.1, A3	C 0.39, A3	—	—
Dimethylethoxysilane [14857-34-2]	0.5	2.1	1.5	6.4
†1,1-Dimethylhydrazine [57-14-7] – Skin	0.01, A3	0.025, A3	—	—
Epichlorohydrin [106-89-8] – Skin	0.1, A2	0.38, A2	—	—
†Ethyl chloride [75-00-3] – Skin	100, A3	264, A3	—	—
†Ethylene glycol [107-21-1]	C 100, A4	39.4, A4	—	—
†Hydrazine [302-01-2] – Skin	0.01, A3	0.013, A3	—	—
†Isophorone [78-59-1]	C 5, A3	C 28, A3	—	—
Lead, elemental, [7439-92-1], and inorganic compounds, as Pb*	—	0.05, A3	—	—
Manganese, elemental [7439-96-5], and inorganic compounds, as Mn	—	0.2	—	—
†Methyl acrylate [96-33-3] – Skin	2, A4	7, A4	—	—
†Methyl hydrazine [60-34-4] – Skin	0.01, A3	0.019, A3	—	—
†Methyl-tert butyl ether [1634-04-4]	40, A3	144, A3	—	—
Nickel, elemental [7440-02-0], insoluble and soluble compounds, as Ni	—	0.05, A1	—	—
Nickel carbonyl [13463-39-3], as Ni	Delete listing; included in listing for Nickel, elemental, insoluble and soluble compounds			
Nickel sulfide roasting, fume & dust, as Ni	Delete listing; included in listing for Nickel, elemental, insoluble and soluble compounds			
Oil mist, mineral Severely refined	—	5[k]	—	—
Mildly refined, as cyclohexane soluble particulate containing polynuclear aromatic hydrocarbons (PNAs)	—	0.2[k], A1	—	—
Ozone [10028-15-6]	0.05	0.01	0.2	0.4
†Triethylamine [121-44-8] – Skin	1, A4	4.1, A4	3, A4	12.4, A4

* A value for blood Pb is under review.
† 1994–1995 Revision or Addition to the Notice of Intended Changes.
(a) Parts of vapor or gas per million parts of air by volume at 25°C and 760 torr.
(b) Milligrams of substance per cubic meter of air.
(f) Fibers longer than 5 μm and with an aspect ratio equal to or greater than 3:1 as determined by the membrane filter method at 400–450x magnification (4-mm objective) phase contrast illumination.
(i) Total dust/particulate.
(j) This TLV is for the respirable fraction of dust for the substance listed. The concentration of respirable dust for the application of this limit is to be determined from the fraction passing a size-selector with the characteristics defined in the "c" paragraphs of Appendix D in the TLV/BEI Booklet.
(k) As sampled by method that does not collect vapor.
A Refers to Appendix A – Carcinogens, in the TLV/BEI Booklet.
A1 – Confirmed Human Carcinogen
A2 – Suspected Human Carcinogen
A3 – Animal Carcinogen
A4 – Not Classifiable as a Human Carcinogen
A5 – Not Suspected as a Human Carcinogen
C Denotes Ceiling Limit.

Transfers to the Adopted List for 1994–1995

Substance [CAS#]	TWA ppm[a]	TWA mg/m3[b]	STEL ppm[a]	STEL mg/m3[b]
Acetone cyanohydrin [75-86-5], as CN – Skin	C 4.7	C 5	—	—
Adiponitrile [111-69-3] – Skin	2	8.8	—	—
Ammonium perfluorooctanoate [3825-26-1] – Skin	—	0.01, A3	—	—
Bromine [7726-95-6]	0.1	0.66	0.2	1.3
1,3-Butadiene [106-99-0]	2, A2	4.4, A2	—	—
Chromium, metal [7440-47-3], and inorganic compounds, as Cr				
Metal and Cr III compounds	—	0.5, A4	—	—
Water soluble Cr VI compounds, Not Otherwise Classified	—	0.05, A1	—	—
Insoluble Cr VI compounds, Not Otherwise Classified	—	0.01, A1	—	—
Cobalt, elemental [7440-48-4], and inorganic compounds, as Co	—	0.02, A3	—	—
2-N-Dibutylaminoethanol [100-37-8] – Skin	0.5	3.5	—	—
Diethanolamine [111-42-2] – Skin	0.46	2	—	—
Diethylamine 109-89-7] – Skin	5, A4	15, A4	15, A4	45, A4
...thylaminoethanol [100-37-8] – Skin	2	9.6	—	—
EPN [2104-64-5] – Skin	—	0.1	—	—
Ethylamine [75-04-7] – Skin	5	9.2	15	27.6
Heptachlor [76-44-8] and Heptachlor epoxide [1024-57-3] – Skin	—	0.05, A3	—	—
Hexachlorobenzene [118-74-1] – Skin	—	0.025, A3	—	—
Hydrogen cyanide and Cyanide salts, as CN				
Hydrogen cyanide [74-90-8] – Skin	C 4.7	C 5	—	—
Calcium cyanide [592-01-8] – Skin	—	C 5	—	—
Potassium cyanide [151-50-8] – Skin	—	C 5	—	—
Sodium cyanide [143-33-9] – Skin	—	C 5	—	—
Mercury [7439-97-6], as Hg				
Aryl compounds – Skin	—	0.1	—	—
Inorganic forms including metallic mercury – Skin	—	0.025, A4	—	—
Methyl-tert butyl ether [1634-04-4]	40	144	—	—
Nitromethane [75-52-5]	20	50	—	—
...pnyl glycidyl ether (PGE) [122-60-1] – Skin	0.1, A3	0.6, A3	—	—
Sodium fluoroacetate [62-74-8] – Skin	—	0.05	—	—
Sulfometuron methyl [74222-97-2]	—	5, A4	—	—
Triethylamine [121-44-8] – Skin	1	4.1	5	20.7

Chemical Substances and Other Issues Under Study

Information, data especially, and comments are solicited to assist the Committee in its deliberations and in the possible development of draft documents. Draft documentations are used by the Committee to decide what action, if any, to recommend on a given question.

Chemical Substances

Acetomethylchloride
Aluminum alkyls
Antimony
Attapulgite/Palygorskite/ Sepiolite
Aviation Fuel
Bentonite
Borax and boron compounds
Bromochloromethane
Bromodichloromethane
Bromoform
1,2,3,4-Butanetetracarboxylic acid
sec-Butyl acetate
sec-Butanol
2-t-Butylazo-2-hydroxy-5-methylhexane
Carbon disulfide
Chlorine
Chlorodiphenyls (42% & 54% chlorine)
Copper fume
Cristobalite
Crystalline silicas
Cyanamide
Dichlorocyclopentadiene
Dichlorodiphenyl sulfone
1,2-Dichloroethane
2,4-D (2,4-Dichlorophenoxy acetic acid)
1,3-Dichloropropene
Diesel Fuel
1,4-Diethyl benzene
N,N-Dimethyl acetamide
Dimethylformamide
Dimethyl disulfide
Dimethylterephthalate
2-Ethoxyethanol (EGEE)
2-Ethoxyethyl acetate (EGEEA)
Ethyl bromide
Ethyl tert-butyl ether
2-Ethylhexoic acid
Fibrous glass dust (synthetic inorganic fibers)
Fluorine
Furfural
Gallium arsenide
Gasoline (unleaded)
Glycol ethers
Glycidol
Graphite fibers
1-Hexene
Hexachlorocyclopentadiene
Isobutene
Isopropyl glycidyl ether (IGE)
Lead, organic compounds
2-Methoxyethanol (EGME)
2-Methoxyethyl acetate (EGMEA)
Methyl n-butyl ketone
Methyl chloride
Methyl propyl ketone
α-Methyl styrene
Methyl vinyl ketone
Methylene chloride
Methylene diamine
4,4'-Methylene dianiline
Mineral spirits
Naled
Pentachlorophenol
Pentane
2,4-Pentanedione
Perlite
Petroleum solvents
Phosphates (including mining)
Picolene
Propylene dichloride
Styrene
Synthetic Inorganic Fibers (Man-made mineral fibers)
Tantalum
tert-Amyl methyl ether (TAME)
1,1,2,2-Tetrachloroethane
Tetrahydrofuran

Tetrakis (hydroxymethyl) phosphonium chloride
Tetrakis (hydroxymethyl) phosphonium sulfate
Tetrasodium pyrophosphate (Phosphates)
Tridymite
Trona
Uranium
Vanadium
Vinylidene chloride
Vinyl cyclohexene dioxide
Xylene

Other Issues

1. Ceiling Limit, Excursion Limit and Short-Term Exposure Limit (STEL).
2. Reproductive Effects Notation. Under further review, but for the present, a notation will not be included in the TLV/BEI Booklet listing.
3. Risk Assessment.
4. Neurotoxicity.

Revisions to the "Introduction To The Chemical Substances," TLV/BEI Booklet

Following the third paragraph, add the following:

"Health impairments considered include those that shorten life expectancy, compromise physiological function, impair the capability for resisting other toxic substances or disease processes, or adversely affect reproductive function or developmental processes."

Particulates Not Otherwise Classified (PNOC)

This section of the "Introduction" is revised to read as follows:

"There are many substances on the TLV list, and many more that are not on the list, for which there is no evidence of specific toxic effects. Where these are particulates, they have frequently been called "nuisance dusts". Although these materials may not cause fibrosis or systemic effects, they are not biologically inert. At high concentrations, otherwise nontoxic dusts have been associated with the occasionally fatal condition known as alveolar proteinosis. At lower concentrations, they can inhibit the clearance of toxic particulates from the lung by decreasing the mobility of the alveolar macrophages. Accordingly, the Chemical Substances TLV Committee recommends the use of the term "Particulates Not Otherwise Classified (PNOC)" to emphasize that all materials are potentially toxic and to avoid the implication that these materials are harmless at all exposure concentrations. To recognize the adverse effects of exposure to otherwise nontoxic dusts, a TLV–TWA of 10 mg/m^3 for inhalable particulate and a TLV–TWA of 3 mg/m^3 for respirable particulate have been established and are included in the main TLV list. Refer to the documentation for Particulates Not Otherwise Classified (PNOC) for a complete discussion of this subject."

Unlisted Substances

This section of the "Introduction" is revised as follows:

"The list of TLVs is by no means a complete list of all hazardous substances or of all hazardous substances used in industry. For a large number of materials of recognized toxicity, there are little or no data available that could be used to establish a TLV. Substances that do not appear on the TLV list should not be considered to be harmless or nontoxic. When unlisted substances are introduced into a workplace, the medical and scientific literature should be reviewed to identify potentially dangerous toxic effects. It may also be advisable to conduct preliminary toxicity studies. In any case, it is necessary to remain alert to adverse health effects in workers which may be associated with the use of new materials. The TLV Committee strongly encourages industrial hygienists and other occupational health professionals to bring to the Committee's attention information which would suggest that a TLV should be established. Such information should include exposure concentrations and correlated health effects data (dose–response) that would support a recommended TLV."

Committee Activities for 1993–1994 Included:

1. New Committee Members: Michael J. Blotzer, CIH, CSP, National Aeronautics and Space Administration, Lewis Research Center; James S. Bus, Ph.D., Dow Chemical Company; Richard E. Fairfax, CIH, Occupational Safety and Health Administration, Seattle Regional Office; Gregory L. Kedderis, Ph.D., Chemical Industry Institute of Toxicology; M. Val Roloff, Ph.D., Monsanto Company, is the American Industrial Hygiene Association (AIHA), Workplace Environmental Exposure Levels (WEEL) Committee liaison to the TLV Committee.
2. Committee and Subcommittee Meetings: The plenary Committee held meetings September 13–14, 1993, in Rockville, MD, and March 7–8, 1994, in Dallas, TX. The subcommittees met individually a total of 10 times during the 1993–1994 interval. These meetings included presentations and receipt of data from interested outside groups relative to Notice of Intended Changes or Chemical Substances Under Study for: Benzene, 1,3-Butadiene, Cadmium, Cobalt, Epichlorohydrin, Hydrazines, Lead, Manganese, Mercury, Methyl-tert butyl ether, Methyl acrylate, Nickel, Oil Mists, and Styrene. Data and research activities associated with the Dusts and Inorganics Subcommittee's considerations of asbestos and synthetic inorganic fibers were presented during the Subcommittee's laboratory site visit to the Chemical Industry Institute of Toxicology (CIIT). Two AIHA WEEL Committee meetings were attended by the TLV Committee Staff Liaison.
3. Federal Republic of Germany MAK and BAT Values: Dr. H. Greim, Chair, Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, attended the March 7–8, 1994 meeting of the TLV Committee. Dr. Greim and Dr. J. Doull, Chair, Chemical Substances TLV Committee, have utilized such liaison to foster teamwork in the international industrial hygiene and occupational health arena.
4. Documentation, Sixth Edition: The Sixth Edition of the Documentation of TLVs and BEIs was completed early in 1994 and distribution completed to all subscribers. The publication, a three-volume companion document to the TLV BEI Booklet, is available from the ACGIH Office; Publication No. 0206.
5. Presentations: Presentations were made by members of the Committee and ACGIH Staff on the process of TLV and documentation development and technical, scientific, and political issues confronting the Committee. Included were a Professional Development Course (PDC) at the 1993 American Industrial Hygiene Conference & Exposition; TLV orientation of industrial hygiene and occupational health graduate students at the University of Cincinnati Institute of Environmental Health; presentations at Local Sections of AIHA: Central Ohio and Northern California; and TLV representation at the International Conference on Crystalline Silica Health Effects.